

ASTRONOMY and ASTRO-PHYSICS.

MAY, 1892.

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PLATE XIV.



HARVARD COLLEGE ASTRONOMICAL OBSERVATORY,
AREQUIPA, PERU.

ASTRONOMICAL AND ASTERO-PLANETARY MUSEUM. 1892.

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WHOLE No. 105

GENERAL ASTRONOMY.

THE MOUNTAIN STATION OF THE HARVARD COLLEGE OBSERVATORY.*

WILLIAM H. PICKERING.

The Boyden Department of Harvard College Observatory was founded in the spring of 1887. By the will of Mr. Boyden a considerable sum of money was left to aid in the establishment of an Observatory "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the Observatories now existing, owing to atmospheric influences." Evidently the first duty of those in charge of the fund was to find a suitable locality for the Observatory. Accordingly the following summer, an expedition was undertaken to Colorado, well-equipped with instruments, and observations successively secured in three localities, namely:—Colorado Springs, altitude 6,035 feet; Leven Lakes (near Pike's Peak) altitude, 10,964 feet, and Pike's Peak, altitude 14,147 feet. At each of these stations a 12-inch Clark refractor was set up, with a portable mounting especially contrived for the purpose. Pike's Peak is probably the greatest altitude at which so large an instrument has ever been used. A quartz spectroscope furnished with two 60° prisms was also employed at each station, and several hundred photographs secured of the solar spectrum. Several of these spectra showed a line at w. l. 292, which is believed to be the shortest wave-length yet photographed in any celestial spectrum. The negative which showed this line to the best advantage, however, was one taken from the lowest station.

An examination of the other photographs showed that no perceptible advantage was gained by an increase of 8000 feet in altitude, and it was, therefore, concluded that the shorter wave-lengths which the Sun, in all probability, gives out from his surface, were absorbed before passing through his atmosphere. With regard to the steadiness of seeing, no appreciable advan-

* Communicated by the author.

tage over Cambridge was shown at any of the stations. The stars were undoubtedly somewhat clearer than at sea level, but this difference only amounted to a fraction of a magnitude. As a final result of the summer's work, it was concluded that the selection of a proper site for an Observatory was by no means merely a question of elevation.

The next expedition sent out by the Department was in the winter of 1888-89. Observations with a 13-inch Clark refractor were made at Willows in northern California, and later, on Wilson's Peak, altitude 6000 feet, in the southern part of the state. The telescope was kept at the latter point for over a year, and continuous observations made every clear night. During the rainless season scarcely a cloud obscured the sky, and the definition was extraordinarily fine. Altogether the station was a decided improvement over Colorado. Nevertheless, there were objections to the location, one being that it was found almost impossible to secure a clear title to any land near the summit of the mountain. For this and other reasons it was decided to seek farther.

In the mean time Messrs. S. I. and M. H. Bailey had undertaken an expedition to the west coast of South America, and had established a station upon Mt. Harvard, altitude 6600 feet, not far from Lima, Peru. This station was occupied for over a year, and very satisfactory results were obtained at it. It was concluded from theoretical considerations, largely meteorological, into which it is not necessary to go at present, that a desirable location ought to be found near the tropics. The Messrs. Bailey explored the coast as far south as Valparaiso, with this point in mind, visiting also several inland cities. Especial attention was directed to Arequipa, and this city was so favorably reported on that it was decided to send the next expedition to that point.

The present expedition left the United States in December, 1890, arriving in Arequipa the middle of the following January. It was then in the height of the cloudy season, which lasts about four months, and little direct astronomical work could be accomplished. Nevertheless a map of the valley was undertaken, a site for the Observatory selected, the land purchased, and the erection of buildings commenced. The clear season opened in April, and soon it was found that the favorable reports given us had in reality far understated the truth. The transparency of the sky was such, that it was a common occurrence to see third magnitude stars set below the horizon where it was on a level with the eye, while at home, as is well known, to see any star set, unless behind some elevation, is an unusual event.

But with the 13-inch telescope the most interesting results were obtained. Ten and twelve diffraction rings have been counted, under favorable circumstances, around the brighter stars, each ring being nearly if not absolutely motionless. It is well known that in general to see the rings at all with a telescope as large as the 13-inch is a rare occurrence, and that the few there seen are nearly always wavering and broken. At first a power of 475 was used exclusively for all observations, saving those requiring a large field, this being the highest power with which we came provided. The definition under these circumstances upon the Moon and planets was absolutely sharp, and without a blur or waver. Since then higher powers have been sent from home, and 1140 diameters have been used upon Venus in the day-time, that power showing the planet to decidedly better advantage than 812. The phases of Jupiter's satellites are readily observed as they enter into the shadow of the planet, a phenomenon which it is thought but few astronomers have ever seen, even with much larger telescopes than the 13-inch.

This telescope, though small compared to the modern giant refractors, is nevertheless the largest visual refractor in use south of 35° north latitude, although there are about thirty larger ones north of this parallel. This fact has therefore enabled us to study all of the more interesting southern objects for the first time with an instrument of this power. As a result many new double stars have already been discovered, together with several faint clusters and nebulae which are probably new. Some of our most interesting observations, however, pertain to the bodies of the solar system, which the high magnifications that we are able to employ enable us to study to great advantage. Descriptions of some of these observations we hope shortly to be able to send to *ASTRONOMY AND ASTRO-PHYSICS*. This telescope, as has been mentioned upon former occasions, has the valuable peculiarity that by reversing the crown lens, and shifting the flint, we may convert it from a visual, into a photographic telescope, of high excellence. Notwithstanding the great interest attaching to the visual work which may be accomplished here, the photographic results which may be obtained by an instrument of this size, so unusually located, are so much more important, that it is very doubtful if many more visual observations can be made with it, and this year its time will be largely devoted to securing spectra of the brighter southern stars.

The city of Arequipa, though the third in size in Peru, having a population of about 29,000, is not well known to the outside

world. The visitor arriving at the Port of Mollendo, passes through a rougher surf than he has probably ever seen upon the Atlantic Coast, and takes the cars of the Southern Railway of Peru one hundred and seven miles across the desert, to his destination. The city itself is situated in a little green oasis containing perhaps sixty square miles, through which runs the River Chile. The Observatory is built upon the crest of a hill overlooking the valley, and about four hundred feet above the city. To the eastward lies the extinct volcano of Pichu pichu, 18,600 feet in height, northeast and but ten miles distant lies the quiescent volcano of the Misti, 19,200 feet in altitude, and to the north, and twelve miles distant, lies Charchaui 20,000 feet in elevation. Although these mountains are so near at hand, yet in no case do they rise over 12° above the true horizon.

The true geographical position of the Observatory has not as yet been accurately determined, but it is, roughly speaking, in latitude $16^{\circ} 24'$ south, and longitude $4^{\text{h}} 45^{\text{m}} 30^{\text{s}}$ west from Greenwich. It is consequently about 4,000 miles south of Harvard Observatory, and about 18 miles west of it. Its altitude is 8055 feet above the sea, and it is therefore considerably higher than any other Observatory in the world having so extensive an equipment.

Owing to our location within the torrid zone, our meteorological conditions are very regular. As we have been here but one year we cannot as yet generalize, but we may say that the clear season is expected to begin the latter part of March or first of April, and to continue with scarcely an interruption from cloud until the first of November. November is the beginning of the cloudy season, and during this month this last year 0.02 of an inch of rain fell. December was fairly clear, while January and February were cloudy and rainy. Nearly all the rain falls in January and March, amounting in general, to two or three inches in all. The mornings, with few exceptions, are bright and sunny throughout the year, most of the rain falling in the afternoon and evening. Excepting during the rainy season the climate is exceedingly dry. With some persons the skin becomes rough, and the lips crack from the excessive drouth. All vegetation is maintained by constant irrigation, for an evaporation of 0.59 of an inch in one day has been recorded in the rainy season. No observations have as yet been made when the weather was really dry. The wind reaches its maximum in the middle of the day, and it is unusually calm at night. The highest velocity noted was December 26, when it reached a velocity of 17.2 miles an hour, but a slight

addition must be made to this figure on account of our rarefied atmosphere.

The barometric pressure and temperature are very uniform throughout the year. Tri-daily observations are maintained and during the clear season a fourth observation is taken in the middle of the night. The highest barometer reading recorded was 22.676 on Aug. 17, and the lowest 22.472 on January 19. The maximum thermometer reading was 79°.0 on June 3, but this was unusually high, the second highest being 74°.3 in October. The minimum thermometer reading of the year occurred eight days after the maximum upon June 11, and was 38°.5. Although the temperature of the air never gets down to freezing, not only do we have occasional frosts, but standing water is known to skim over with ice during the clear season, such is the excessive radiation. The power of the Sun is at times tremendous, and a blackened bulb thermometer exposed to its rays in vacuum has been known to reach 164°. We have sometimes had difficulty in our tool room in the afternoon, when the Sun shone in, as the tools become so hot, that we could not handle them, without first putting them in the shade to cool. It is not pleasant to be out in the middle of the day during the clear season, but in the shade, upon our verandah it is never uncomfortably warm and the middle of the day there is always a cool breeze blowing. I have gone into considerable detail in describing our meteorological conditions, as I am inclined to think that they have more to do with our favorable seeing, than has our elevation of 8,000 feet *per se*. Of course they may be said to depend upon it, more or less, but still, we might have the same elevation elsewhere, and be very differently circumstanced meteorologically. From my experience with large refractors in different parts of the world, I am inclined to attribute our exceptionally steady seeing more to the excessive dryness of our climate than to any other one cause.

AREQUIPA, Peru, March 1, 1892.

THE BOYDEN STATION OF THE HARVARD COLLEGE OBSERVATORY.*

WILLIAM H. PICKERING.

In the foregoing paper I gave an account of the situation and the meteorological conditions prevalent at the Peruvian station

* Communicated by the author.

of this Observatory. In the present paper I shall describe its equipment, and the class of work to which it will be especially devoted. A general idea of its situation may be obtained from the plate* accompanying this article. The great mountain mass in the background is Charchaui, an extinct volcano, 20,000 feet in altitude, whose crater was probably originally some six miles across, and whose summit is twelve miles distant from the Observatory in an air line.

At the bottom of the snow line in this picture, and almost exactly under the deep *cañal* situated to the left of the main summit, lies a plateau, rather less than half a mile square. Near the front edge of this plateau, where it drops off in a precipice several hundred feet deep, stands the upper meteorological station of the Observatory—the highest observing station in the world. A more detailed account of our various meteorological stations, and of our topographical and barometrical determinations of their altitudes, will be reserved for a later paper, where they can be discussed to more advantage.

The accompanying photograph was taken in a direction nearly due north, as may be seen by the orientation of the sides of the buildings. To the west and south the land slopes away gradually, but on the east, it descends sharply some two hundred feet to the river valley. On the opposite side it rises, at first gradually, and later, more and more steeply, to the summit of the Misti, some ten miles distant. As the land had not been purchased one year, when this negative was taken, February 11, 1892, much still remains to be done,—such as clearing the grounds, laying out paths, etc. The erection of the house itself consumed considerable time and thought, as very little building is done in this place, and the party had to be its own architects. The house is now completed, however, and has proved to be very satisfactory.

On the left of the house is seen the dome of the 13-inch telescope. The walls of the building are constructed of wood, being a single thickness of board, in order that they may take the temperature of the outside air as rapidly as possible. The revolving portion is built in the form of a drum, and consists of a wooden frame and boarded roof, covered with canvass. Its walls are framed upon three wooden rings, one at the top, one at the bottom, and one in the middle. The bottom ring is complete, but the middle one is broken on the side where the shutter opens. The upper ring is also broken, on the side turned away in the picture, and here a smaller opening is made, closed by two shutters, one in the side

* See Frontispiece.

and one in the roof. By this plan, the chief objection to the drum form of dome is avoided, and any portion of the sky can be observed at any time, through one or the other of the two openings. A ladder permanently attached to the outside of the drum, but not shown in the picture, leads onto the roof and has been found extremely convenient on several occasions. The main, side and roof shutters are made in separate pieces, any one of which can be opened independently of the rest. This is especially important when carrying on photographic work upon windy nights. It is less important in this locality, however, as the nights are almost invariably calm. All of the shutters open outward upon hinges, as shown in the photograph and are managed by cords from the floor of the dome. Indeed, it seems to me that this form of dome, if so modified as to be adapted to the climate of the temperate zones, would be generally found not only very much cheaper, but very much more convenient than the ordinary hemispherical form. The height from the floor to the bottom of the cross ties inside the roof is twenty-four feet, which is also the diameter of the drum. The drum revolves upon independent iron wheels, and can be readily turned without mechanical aid, with one hand.

The telescope contains no unusual features save the reversible lens, previously referred to, and a device for reading the right ascension directly without computation, as one does the declination. A 12-inch prism is attached in front of the object-glass, and is so counterpoised that it may be pushed to one side without altering the adjustment of the instrument. It is proposed to employ this telescope for photographing the brighter stellar spectra, for the charting of clusters, the measurement of close double stars, and the study of planetary and lunar detail. To the telescope is attached an 8-inch, and a 1½-inch finder, the latter having a field of about nine degrees in diameter.

In front of the dome and to the left of it is the laboratory, containing the offices, work-room, tool-room and photographic rooms of the Observatory. These rooms are fitted up in the manner that experience has shown to be most convenient, and need no farther comment.

Between the laboratory and dome is the shed covering the 20-inch reflector. It is of only 42 inches focus, and is one of the pair made by Mr. Common for use during the second solar eclipse of 1889. This instrument is especially adapted on account of its great aperture and short focus to the study of faint nebular detail. The shed covering it slides forward upon a track, leaving

the instrument entirely exposed to the sky. To the east of this instrument, but hidden behind the house, is the meteorological shelter, made in the customary form, and carrying upon its roof a Robinson anemometer, wind-vane and a pair of sunshine recorders of the form adopted by Harvard College Observatory.

North of the meteorological shelter are the transit pier and clock room, the latter a small stone structure with a stone roof, supported upon iron rails. From the pier a view of the sidereal clock may be obtained through a glazed window. Notwithstanding the intensity of the sunlight, it is found best to open the clock room slightly in the middle of the day, otherwise its inside temperature will be lower at mid-day than at midnight. This is due to the slow conduction of heat by the stone walls and roof. The clock room is connected by wire with the laboratory and dome. Four wires lead to the former and may be faintly traced in the picture, although photographed from a distance of over nine hundred feet.

In the clock room are placed the earthquake recorders. This arrangement is only temporary, however, and a separate building will be constructed for them later. Whenever an earthquake occurs, it is announced automatically upon a bell in the laboratory, and a clock is stopped at the same time by electricity. Many of these earthquakes occur in the course of a year, but they are usually so slight that they would pass unnoticed if one were standing, save for the rattling of the doors and windows which is sometimes heard. Usually the pen of the siesmograph merely makes a little hole in the lampblacked surface of the glass plate on which it rests, but in two instances thus far, a distinct and complicated curve has been drawn.

Several severe earthquakes have, at different times, been felt in this locality, and accordingly every precaution has been taken in the erection of buildings and instruments, to render them perfectly secure. The base of the iron pier of the telescope is buried five feet deep, in a mass of solid masonry, eight feet square, whilst the dome is built as lightly as possible. This is the most approved form of construction for buildings in earthquake countries, because in case of a severe shock, being very light, they merely shake about, but do not come down. In the case of the dwelling house, on the other hand, where warmth was a *desideratum*, it was necessary to construct it of stone, but the pillars are pierced in each case from end to end by an iron bar, and they and the walls are all bound together by railroad iron, passing under the floor of the rooms. No plastering is employed upon

the ceilings, but all are made either of wood, or of stone, securely supported upon iron rails, the latter being the customary construction here among the better class of houses. The walls of the upper story are of bamboo, small stones, and stucco. Thus the house, while it is in outward respect quite similar to northern dwellings, is, in its internal structure, quite unlike them. We have been often asked if the frequent earthquakes would not throw our instruments out of adjustment. So far, however, we have had no more trouble than we would have had at home, where after the frosts, the ground always settles somewhat under the piers. If the earthquakes shake the instruments, they apparently let them settle back again into their original positions.

To the east of the meteorological shelter, and also behind the house, is the 5-inch visual telescope. It is intended to use this instrument later for solar work. To the left of the laboratory is seen the shed covering the 8-inch Bache telescope. Over thirteen hundred 8×10 photographs have been secured with this instrument during the past year, some of them being star charts and others stellar spectra. Between the Bache shed and the laboratory is seen the somewhat pyramidal prime vertical pier. Its summit furnishes our bench mark for altitude, and is exactly on a level with the floor of our upper piazza. It has been used hitherto chiefly for surveying purposes.

To the left and below the Bache shed lie the stable and servants' quarters, and just above them, with its white canvas cover thrown back is found the 2½-inch camera. This instrument is of exceptionally short focus, and it is with it that the great outer spiral of the Orion nebula was discovered two years ago at the Boyden station in California. The mounting, however, which is new, is not yet satisfactory, and we hope to improve upon it shortly. We have, nevertheless, already found with it that the Greater Magellanic Cloud is also a spiral structure, similar to the Orion nebula, but with the center less condensed, and the outer regions much more so. The great nebula of 30 in Dorado is near, but not coincident with the center. This wonderful object, second only in the whole heavens to the Orion nebula, is, however, unlike it in being very non-actinic, and we have only succeeded in photographing the very highest portions of it hitherto with the large telescope. Its spectrum is also probably gaseous.

It is expected that in a year or so, we shall receive from the United States a 5-inch photographic meridian photometer, for

determining the photographic magnitudes of all the brighter stars south of the equator. Also later the 24-inch photographic doublet, known as the Bruce telescope, modeled after the Bache, but constructed upon three times the scale, with which it is intended to make a complete chart of the heavens. In fact, our equipment will be excellent in many respects, and the chief instrument which we are at present lacking is that which many would consider the most important of all, and which we do, undoubtedly, very much need, and that is a first-class large visual refracting telescope. It has been often said that the chief obstruction at present to astronomical advance was our own atmosphere. But this obstruction has now, at this station, been practically overcome, and what we see here depends not as elsewhere upon the condition of the air, but only upon the size and quality of the telescope employed.

AREQUIPA, Peru, March 7, 1892.

RADIANT ENERGY AS A PROBABLE CAUSE OF THE SOLAR CORONA, THE COMÆ AND TAILS OF COMETS AND THE AURORA BOREALIS.*

SEVERINUS J. CORRIGAN.

According to the hypothesis advanced in my paper entitled "The Transmission of Radiant Energy through Gaseous Media," and published in Nos. 101 and 102 of *ASTRONOMY AND ASTROPHYSICS*, the component atoms of each molecule of any gas are regarded as being in incessant and exceedingly rapid revolution around a focus situate within the molecule. If this be true, it is, I think, reasonable to assume that these rapidly moving atoms can, and do, take up an indefinite number of finely divided, or exceedingly minute particles of any solid, liquid or gaseous matter against which they may impinge, and that, from their own inherent store of energy they can, and do, impart motion to such assumed particles. We can conceive that such matter is transferred from molecule to molecule, as if by a train of revolving wheels in intimate contact with each other, and that it is thereby diffused, more or less rapidly, throughout any gaseous mass which is in any way in contact with the solid, liquid or gaseous matter aforesaid. The diffusion of gases is a well-known phenomenon of Physics, and it is clearly explicable under this hypothesis, as is also the phenomenon known as evaporation.

* Communicated by the author.

According to this view, when the particles of a liquid mass, water, for instance, are sufficiently separated by the impulses emanating from the vibrating, *i. e.*, heated atoms of a containing vessel, or, in other words, by the action of applied heat, which occurs when the water has reached the temperature of ebullition, they are, by the energy of the applied heat, forced in amongst the revolving atoms of the occluded and the superincumbent gas, against the pressure of such gas, and are endowed with a portion of the energy of motion possessed by these moving atoms.

Since the quantity of energy resident in any moving body depends not only upon the linear velocity, but also upon the mass of the body moved (being equal to one half the mass into the square of the velocity), the greater the quantity of aqueous particles taken up and set in motion by the rapidly revolving atoms of the gas, the greater will be the tension or pressure of the resulting vapor, or, in other words, the greater will be the ability of such vapor to perform work. It is a well-known fact that the weight of any given volume of steam increases with the pressure of the latter, being greater on account of the greater number of watery particles assumed and set in motion by the rapidly revolving atoms of the sustaining air. I hold, therefore, that without an occluded or a superincumbent gas there can be no evaporation. This statement may seem to run counter to observed facts relative to evaporation *in vacuo*, but it should be noted that according to the hypothesis which I have advanced in No. 101 of ASTRONOMY AND ASTRO-PHYSICS, what is called a vacuum, ordinarily, is very far from being one in so far as inherent energy is concerned.

The above enunciated hypothesis enables us to clearly define the difference between a *gas* and a *vapor*; viz.: that the latter consists of solid or liquid particles sustained in rapid motion by the revolving atoms of a true or permanent gas.

Strong observational proof can be adduced in corroboration of said hypothesis. It is a matter of common observation that when an incandescent electric lamp has been in use for a considerable length of time, the inner surface of the glass bulb becomes blackened; this blackening is found to be due to carbon particles which have been forced against the glass with considerable violence, since they adhere quite firmly thereto. The only source from which these particles can come, being the carbon filament, which is found to have undergone an appreciable waste, the question arises, how have they been transported across the highly

vacuous space between the filament and the inner surface of the glass globe? The hypothesis above stated furnishes a rational answer, viz.: that the particles of carbon are transported by the revolving atoms of the remanent gases, namely, nitrogen and carbonic acid gas, included by the glass bulb, and which, as stated above, act like a train of revolving wheels in contact with each other, the particles being taken from the filament by the revolving atoms in contact therewith, passed along by the intermediate molecules, and finally deposited upon the glass by the revolving atoms impinging against it; in other words, the transportation of the particles is a result of evaporation or of diffusion.

If the truth of the hypothesis advanced above be admitted, a probable cause of the phenomena mentioned in the title of this paper can be proposed. The first mentioned is the solar corona, that luminous apparition surrounding the Sun, and visible to the naked eye at time of total solar eclipse. We know that the surface matter of the solar globe is composed of gases and the vapors of many kinds of matter, and that the Sun is constantly emitting intense, thermal, luminous, and electrical radiations which are transmitted throughout surrounding space. Now, if the hypothesis above set forth in regard to the cause of diffusion and of evaporation be true, the vapors surrounding the solar globe should be urged outward into space, by the Sun's radiant energy, as if impelled by a force acting in opposition to solar gravity, and luminous vaporous matter so radiated, would appear as the corona, and possibly, as the zodiacal light. I would here adduce collateral evidence to support the hypothesis of the existence of a force, or *quasi* force, near the Sun's surface, acting in opposition to solar gravity. In No. 75 of *THE SIDEREAL MESSENGER*, I called attention to the remarkable fact that the time of rotation of any planet of the solar system appears to be a function of the density of the planet the Earth's time of rotation and density being each taken as unity. In each case, the time of rotation is very nearly proportional to the square root of the density and I endeavored, in my paper published in the above mentioned number of the *MESSENGER*, to demonstrate, mathematically, the cause of this peculiar relation. I also called attention to the fact that it exists in the case of every one of the eight planets of our system, but *not* in that of the Sun, and I showed that this exception could be well accounted for under the hypothesis that there is an apparent force emanating from the Sun, and acting in opposition to solar gravity, driving off the vaporous surface matter of the Sun to form the corona.

As a result of the demonstration above referred to, I found, and published, in the paper aforesaid, the following equations:

$$T = \frac{D}{\sqrt{\frac{k}{r^3}}} = \frac{D}{\sqrt{\frac{M}{r^3}}} = \sqrt{D}$$

in which D represents the density, T the time of rotation, k the unit of attractive force, and M the mass of the body under consideration, all of these quantities being relative to the corresponding ones proper to the Earth, and which are taken as the units. Now the density, time of rotation, radius, and mass of the Sun are quite accurately known, so that the only quantity that can be regarded as undetermined is k , or the unit of attractive force; it is true that in so far as the action of the Sun upon the planets is concerned, k is proportional to M , and is therefore known, but the mass, M , of the Sun, is derived from the motion of the Earth around that body, and if there be in action against the surface matter of the Sun a force directly opposed to gravity, but whose influence does not extend to, or, at least, has no effect upon the planetary bodies whose motions are dependent upon M , the quantity, k , in so far as it affects the Sun's surface matter, will not be proportional to M , and although the values of the mass and radius, and, therefore, of the density, be accurately known, they will not give the true relative time of rotation of the surface matter, through the equations above set forth; a repellent force would lessen k , and therefore increase the time of rotation of the surface matter, which is the time observed, and this is what happens in the case of the Sun, the time observed being much greater than that given by the hypothesis.

The existence of such a force renders comprehensible the observed fact of the extreme mobility of the surface matter of the Sun, which mobility is indicated by the opening and closing of spots or cavities covering millions of square miles of the Sun's surface, and the upheaval of vast quantities of solar matter to the height of several hundred thousand miles, often in a space of time so short that a force capable of producing the observed effects is, judging from terrestrial analogies, almost inconceivable.

If the formation of the solar corona be due to the cause above stated, the nature of the operation which forms the coma and the tail of a comet becomes, I think, at once apparent. Radiant energy proceeding from the nucleus, or the central portion of the comet, drives outward the vapors which constitute a great part of the cometary mass, and as the comet approaches the Sun, these vapors are impelled in a direction away from the latter

body by the radiant energy emanating therefrom and form the tail of the comet. Since it is known that evaporation takes place more quickly as the atmospheric pressure decreases, and since the diffusion of vaporous matter, above referred to, is akin to evaporation, the rapidity of formation of the tail of a comet as that body, moving in the highly vacuous regions of space, approaches the Sun, is clearly explicable.

Auroral phenomena are so peculiar that they may, at first sight, seem to be inexplicable by the hypothesis above set forth, but if we accept as most probable, that view which regards the aurora as due to electrified matter in the form of aqueous vapor, or ice particles such as constitute the cirrus cloud, and that this electrified matter is in motion at a very great altitude in the Earth's atmosphere, I think that it can be shown that the aurora can be properly classed, in so far as its cause is concerned, with the phenomena above regarded as results of radiation. We know that the frequency of the aurora varies with that of the Sunspots and that these spots indicate abnormally great disturbance of the solar matter and therefore, abnormally great emission of radiant energy. This excess of radiant energy produces excessive evaporation, and drives the matter so evaporated, and electrified, (probably by the act of evaporation) into a region of the atmosphere much higher than that in which such matter could be normally sustained. The motion of such electrified matter, suspended, probably, above a stratum of rare, dry, non-conducting air, must cause it to act by induction upon the Earth, and thus to generate those disturbances of the magnetic needle, and the other electrical phenomena which are known to accompany the aurora. The formation of the latter is, therefore, analogous to that of the tail of a comet, but there is this important difference, viz.: that the vaporous matter of the aurora is not driven off in a direction exactly away from the Sun, as is the cometary matter, but being electrified, it is acted upon by the Earth's magnetism (which is itself probably a result of solar radiation), and is forced thereby to assume a peculiar conformation, or to set itself along the magnetic lines of force, or parallel to the magnetic meridian.

In this connection reference may be made to the fact that auroræ and the tails of comets both display phenomena which seem to be electrical, and which point to the same or a similar origin for both.

It should be noted that what I have called the *force* producing the effects above mentioned, *i.e.*, the repulsion of matter from the

surfaces of the Sun, Earth, and comets, is not of the same nature as gravity, and, strictly speaking, is not a repellent force at all (although in so far as its effect upon vaporous matter is concerned it acts like such a force), for if it were, the motions of the planets and other bodies of the solar system would be different from what they are well known to be.

The vaporous matter at the surface of the Sun, and the other bodies aforesaid, is simply taken up by the rapidly revolving atoms of each molecule of gaseous matter by which these bodies are surrounded, and carried outward, passing from molecule to molecule with great rapidity in highly vacuous space, while the only effects produced upon the planets are thermal, electrical and luminous. Only vaporous matter, or matter so finely divided that it can be assumed by, and intimately connected with, the revolving atoms, is subject to the action of this *quasi* force, and, therefore, the objections that can be urged against the existence of a force of repulsion, as it is generally understood do not apply in this case.

The action is, probably, the same as that which operates in the case of the incandescent electric lamp, in which particles of the heated carbon filament are carried outward to the sides of the glass bulb by "radiant energy," *i. e.*, by the action of the rapidly revolving atoms of the molecules of the gaseous matter which constitutes the transmitting medium.

In fine, setting aside all theoretical considerations, it is, I think, reasonable to assume that, if radiation from the heated filament of the electric lamp aforesaid, can produce the effects noted, radiation from the heated bodies of the solar system must produce similar effects, upon a scale proportionate to the magnitude of the radiating masses.

ST. PAUL, March 25, 1892.

GEORGE BASSETT CLARK.*

J. A. BRASHEAR.

"Great truths are the simplest
So are the greatest men."—ANON.

It would seem almost like a work of supererogation to write a biography of such a man as George B. Clark.

If a man's work is to live after him, surely, he who by his life work has left his "footprints among the stars" so that they

* Communicated by the author.

may be traced in the ages to come, needs no better, no grander panegyric.

It is not, therefore, to praise his life work that these lines are written, and, indeed, few men of his great worth had such an innate shrinking from publicity as did Mr. Clark, but when such a man has laid down his armor, and has gone to his rest those who knew of his great work in "pushing outward the borders of human knowledge," treasure the incidents in the life history that led to such remarkable results.

In a most interesting article written by Professor Newcomen in 1874, on the Washington telescope, these words occur:

"When we trace back the chain of causes which led to the construction of the great Washington telescope we find it to commence with so small a matter as the accidental breaking of a dinner bell in the year 1843 at the Phillips Academy, Andover, Mass.

One of the scholars of the Academy, George B. Clark by name, gathered up the fragments of the bell, took them to his home in Cambridgeport, put them into a crucible with some tin, and proceeded to melt them in the kitchen fire. His mother very naturally inquired the cause of such an interference with the culinary arrangements, to which he replied that he was going to make a telescope. Having melted his metals he cast them into a disc and commenced grinding them into a concave mirror.

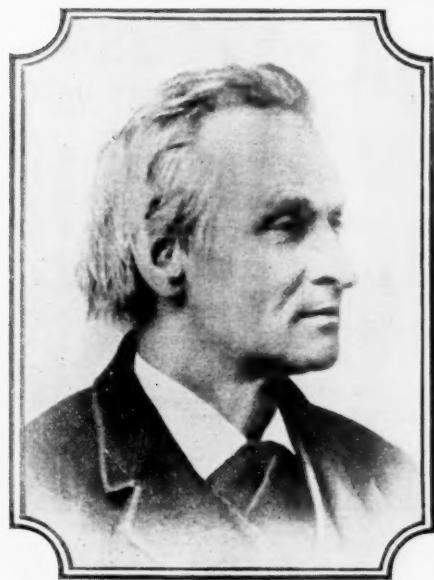
His father, learning what he was doing, lent a helping hand, and the combined skill of father and son was soon rewarded by the completion of a five-inch reflecting telescope which would show the satellites of Jupiter, the rings of Saturn and other telescopic objects. Such was the origin of the now well-known firm of Alvan Clark & Sons."

Years ago the writer asked Father Clark what became of that first mirror, but he could not remember. Thus it was, that, while the great work that Alvan Clark & Sons began in so small a way as the making of that five-inch mirror, there was evidently a genius for the work only waiting for an opportunity to be developed.

George Bassett Clark was born Feb. 14, 1827. He received his early education at a grammar school, high school and at Mr. Whitman's private school in Cambridge. He entered Phillips Academy, Andover, in 1844.* After leaving the Academy he was

* As Mr. Clark's parents desired him to go to Harvard College, he was examined by Professor Benjamin O. Pierce, who pronounced him fit for the Sophomore class, except perhaps in Greek, which he could master sufficiently to pass with credit; but instead of that he chose to go at once into active life.

PLATE XV.



GEORGE BASSETT CLARK.

Feb. 27, 1827-Dec. 30, 1891.

ASTRONOMY AND ASTRO-PHYSICS, May, 1892

employed in civil engineering on the Boston and Main Railroad, and the Ogdensburg and Lake Champlain Railroad. He went to California in 1848 but soon returned. After his return he started business as a maker and repairer of instruments in east Cambridge, and was subsequently joined by his father and brother.

In 1857 he was married to Jennie M. Moseley. In 1860 the place of business was removed to Cambridge where it still continues.

The early work of the Clarks was confined to reflecting telescopes; but soon developed into that class of instruments—the refractor—upon which they have achieved a success second to none in the world. Indeed, so intimately has the name of Clark been associated with the progress and development of the achromatic telescope and the discoveries made with them during the past half century, that, if we were to blot out that record, it would take from the pages of scientific discovery, in the domain of astronomical research, the grandest part of that record.

The history of the great objectives made by Alvan Clark & Sons, from the memorable one sent to Dawes of England to the culmination of their great work on the 36-inch glass of the Lick Observatory, is so well known to the readers of this journal that it were useless to repeat it; but it is not known, perhaps, so widely that Geo. Clark was the master mechanician of the firm, and none knew this better than the astronomers of Harvard Observatory whose confidence in him as an accomplished mechanician was unlimited; and the discoveries made at this famous Observatory are very closely related to the life work of George B. Clark. Much of his time and genius as a mechanician was devoted of late years to the development of the instrumental equipment of the Draper memorial work, in which such signal and valuable results have been obtained, and it was with profound regret that he was compelled to give it up when he was attacked with the illness that ended his useful life.

Mr. Clark was a member of Professor Winlock's eclipse party at Shelbyville, Kentucky, in 1869. He was urged to join the party that went to Spain as well as Dr. Draper's party in 1878, but these invitations he had to decline because of the pressure of occupation at home. His services were always in demand and were eagerly sought after by the astronomers of eclipse expeditions.

On the 9th of January, 1878, Mr. Clark was unanimously elected a member of the American Academy of Arts and Sciences, his special department being that of Practical Astronomy and Geodesy.

This honor was entirely unsought, as far as is known, he knew nothing about his being proposed as a member until he received notice of his election.

In 1882 he was elected a member of the Count Rumford committee on which his name was continued year after year. Honors were thrust upon him from time to time, but they never had more effect upon him than that which is felt by every man of real worth, *i. e.*, an incentive to nobler and better efforts, if such were possible.

The writer has spent many a delightful hour with Mr. Clark in the old Cambridge workshop. He never cared to work when a friend dropped in to see him, and many a noted personage made the old workshop a frequent stopping place, and these pages could be filled with the reminiscences gathered on my visits to Cambridgeport. The poet Longfellow was one of the welcomed visitors, and liberty is here taken to tell of one of those charming reminiscences as told me by Father Clark. A telescope had been finished and set up in the shops; Longfellow dropped in and after looking it over with interest, he remarked: "Clark, that looks like a cannon." He immediately added: "How much better for the peace of our loved country than a cannon."

George Clark was one of the most unpretentious men, kindly in disposition, unselfish, generous; so like his father that to write of one includes both. Friend of nature the song of the bird was ever sweet to him, and it was one of his great regrets during his illness that the song of the birds—aye, even of the frogs in the pond near his summer home was lost to his ear. So tender was his nature that he never would take a gun with him to the woods. I quote the words of one who knew and loved him best. "He had a great love of nature, the woods were a perpetual delight to him; to hear a bird sing, to watch its fluttering wings, to hear the winds through the trees, to find the wild flowers of the wood, to him was purest delight, but he did not enjoy gunning or *injuring any living creature.*"

He was never frivolous, but loved to chat upon his favorite themes—which were always of an elevated character.

He loved poetry and among all poems, he loved "Thanatopsis" perhaps the best of all. Gray's Elegy was also a favorite. Friday, before his death, he desired Gray's Elegy read to him and on Saturday night, asked for Thanatopsis, after the reading of which he remarked, "No one ever wrote anything better than parts of that poem."

"He loved truth, and duty was ever the key note of his life so

far as intercourse with others was concerned—and it was only his own good that was too often uncared for." I quoted those words from one who knew him better than all others.

Like too many of the world's great workmen, Mr. Clark overtaxed his powers—and on the 14th of April, 1889, he had an attack of aphasia. Surgeon General Holt pronounced his case a very serious one, and said he must rest at once; that only a long rest would give him a lease of life. He gained in strength so rapidly that in a few weeks he was enabled to go back to the works, and he thought by applying himself less closely, he might be able to finish the Draper work then well under way. It seemed he could not rest content away from the work he loved so well, but as he was a sufferer from insomnia, he could not build up—and in March of last year he was taken worse and the physician pronounced the trouble as lesion of the nerve centres. He was again compelled to relinquish work and spent a few weeks at Vineland, New Jersey; then took a cottage at Bedford Springs, Mass. His hold on life seemed to be most wonderful and he kept up until tired nature refused to respond to the demands of his indomitable will, although the physicians thought at one time he would rally and be restored to health and usefulness again; but on Thursday, Dec. 24, he overtaxed his strength, and although he was evidently worse, he had the pleasure of the company of his dear old mother and another valued friend to dine with him and his companion on the following day—which was Christmas.

But the summons had come, and his life was fast ebbing away. After a drive to Park Square in Boston, still holding on to the slender thread—as he would hold on to a problem in astronomical engineering, he returned home, soon became unconscious,—never regaining that which had made him a man among men, and at two o'clock in the afternoon of December 30, 1891—with-out fear of the grim monster that will claim us all, he fell asleep—with a fond hope that he might be permitted to solve some of the unsolved problems of his loved study in the great beyond.

Thus has passed away one who has devoted a life to the advancement of human knowledge—who has contributed a large share in the advanced researches of the latter half of the eighteenth century—a man whose name need not be engraved upon a marble tablet—nor upon the lasting bronze, for it is already written among the stars—where it shall be read as long as men point the mighty tube towards the stellar depths.

The portrait of Mr. George B. Clark that faces page 368

of this number of "Our" Journal is a very faithful likeness of him as the writer knew him in the later years of his life. A loving wife, an aged mother and his brother, Alvan G. Clark survive him.

"He has loved the stars too fondly
To be fearful of the night."

HISTORY OF THE COLOR OF SIRIUS.*

T. J. J. SEE.

GEMINUS.

This astronomer was probably a contemporary and associate of Hipparchus. In the "Elements of Astronomy" (the edition of J. P. Migne, Paris, 1857, is the best) he argues logically and at great length against the belief that the conjunction of the Sun with Sirius causes the intense heat of summer; and in the course of his remarks says:—

"οὐ γάρ ἀστέρ (χώρα) οὐτος τῆς αὐτῆς οὐσίας κεκοινώνεται πᾶσι τοῖς ἀστροῖς. Εἴτε γάρ πύρινά ἔστε, εἴτε καὶ αἰθέρια τὰ ἀστρα, τὴν αὐτὴν ἔχει δύναμιν πάντα, καὶ ὅφειλει καταρρατεῖσθαι ὅποι τοῦ πλήθους τῶν ἀστρῶν ἡ ἀπὸ τοῦ κυνός ἀποφορά."

(p. 849 of Migne's edition).

[For this star (Sirius) is of the same nature as all the rest of the stars. And whether the stars are fiery (*πύρινα*) or clear (*αἰθέρια*), all have the same power, and exhalations ought to proceed from the multitude of the stars rather than from Sirius].

It is evident that *πύρινα* refers to the red stars and *αἰθέρια* to the white (or "clear") ones. Geminus, therefore, affirms indirectly, but emphatically, that Sirius is *πύρινος*, while the multitude of stars are *αἰθέρια*. But "all stars have the same power," and he rightly concludes that a red star such as Sirius exercises no more influence upon the earth than a white one. The contrast between the color of Sirius and that of the multitude is perfectly distinct, and since the language above quoted is that of a professional astronomer its truthworthiness can not be questioned. To my mind the above passage alone is a conclusive proof of the ancient redness of Sirius, the more so since Geminus shows himself unfettered by popular belief, and argues logically against the palpable fallacy that "Sirius causes the intense heat of the Dog Days."

* Communicated by the author. (Continued from page 274.)

ERATOSTHENES.

An edition of the "Catasterisms" was published at Frankfort in 1817 by F. C. Marthiae. On examining it I find, strange to say, no color assigned to any star except Vega, which is called white (*λευκός*). In the notes on the planets (evidently derived from an astrological source) Mars is called "*πυροειδής*" and Venus "*λευκός*." Concerning the constellation *χίων*, Eratosthenes says:

"Ἐγει δὲ ἀστέρας ἐπὶ μὲν τῆς κεφαλῆς (ά, ὡς Ἰσις λέγεται) ἐπὶ τῆς γιάττης ἀ, ὡς καὶ Σετρων καλοῦσται μέγας δὲ ἐστε καὶ λαμπρός (τοῦς δὲ τοιωτας ἀστέρας ἀστρολόγοι Σετρίων καλοῦσται, οὐά την τῆς φλογῆς κίνησιν)." (p. 67.)

We shall presently see that the "two stars," Isis and Sirius, are only *two names* for the same star, but the error is faithfully copied by Hyginus. In saying that "Astrologers call such stars Sirians on account of the motion of the flame," Eratosthenes commits another error, which Hyginus has likewise copied. For we have seen that the name *Σετρίων* was used by Hesiod five centuries earlier to denote Sirius alone and that it means the "burning one," as is evident from the language of Hesiod and Aratus. The very uncritical "Catasterisms" of Eratosthenes, therefore, throw no light upon the color of Sirius.

HYGINUS.

The author of the "Poeticon Astronomicon Libri IV" (edition of Dr. B. Bunte, Leipsic, 1875), was a native of Spain and freedman of the Emperor Augustus, by whom he was made chief of the Palatine Library. From the "tyro-like" mistakes in the works of Hyginus critics have generally agreed that they were composed before he had fully mastered the Latin language. The name of Eratosthenes is often mentioned, and a very superficial examination will show that the work is merely a distillation of Eratosthenes' Catasterisms, to which are added some notes on the planets evidently derived from some work on Astrology, of which nothing is now known. The authority of Hyginus is certainly not original. Concerning Sirius he says:

"Sed canis habet in lingua stellam unam, quæ ipsa canis appellatur, in capite autem alteram, quam Isis suo nomine statuisse existimatur et Sirion appellasse propter flammæ candorem, quod ejusmodi sit, ut præceteris lucere videatur. Itaque quo magis eam cognoscerent, Sirion appellasse." (Lib. II, XXXV, p. 74).

Again:

"Hic canis habet in lingua stellam I, quæ Stellæ Canis appell-

latur, in capite autem alteram, quam nonnulli Sirion appellant, de quo prius diximus." (Lib. III, XXXIV, p. 95).

It is to be observed that Hyginus says the star in the tongue is called Canis, whereas Eratosthenes says it is called Sirius; and the star in the head, called by Eratosthenes Isis, is called Isis or Sirius by Hyginus. The confusion is therefore extreme, but we shall presently see that there was only one star with two names (or rather three—Canis, Isis and Sirius) which was spoken of sometimes as "in the tongue" and sometimes merely as "in the head." If in Hyginus' rendering of Eratosthenes' "*διὰ τὴν τὴν φλόγην κίνησιν*" by "propter flammæ candorem," "candor" has any definite meaning at all, it is "light" or "brightness," not "whiteness." Cicero uses "candor" in this sense:

"Solis candor illustrior quam ullus ignis."

(De. Nat. Deor. II, 15.)

"Ut cum videmus speciem primum, candorumque cœli."

(Tusc. Quæst. I, 28.)

Hyginus' remarks are, however, in no case to be taken as the result of observation, but merely of book-work, as is shown by the way he copies Eratosthenes, and by the astrological sources of his information implied in the use of "figura" for "color":

Mars: "figura est similis flammæ."

Jupiter: "figura autem similis Lyrae"—meaning apparently, that Jupiter is of the same color as Vega.

Saturn: "Colore autem igneo, similis ejus stellæ quæ est in humero dextro Orionis."

M. Georges Lafaye in the "Mélanges d'Archéologie et Histoire de l'Ecole Francaise de Rome," 1881, has a very interesting paper entitled "Un Monument Romain de l'Etoile d'Isis." In this paper the author shows clearly that Isis was a general name for Sirius among the Egyptians. The star was also called (in the Decree of Canopus) Sopet; elsewhere sometimes Sepet, Sept, Set, and finally Sot, Soti, or Sothi, which, when given the Greek ending, becomes Sothis, the Egyptian word for Sirius in common use among classic authors. It has also been suggested that Thoth the first month of the Egyptian calendar, is named from Sothis, the heliacal rising of which marked the beginning of the fixed year (of 365½ days) and also of the "wandering" year (of 365 days) at the beginning of a Sothic period. M. Lafaye mentions a Temple at Assouan especially dedicated to the worship of Isis-Sothis, and shows that the Egyptians regarded Sirius as the soul

of the goddess Isis transferred to the heavens; wherefore special ritual honors were accorded her spirit, and the worship of Isis-Sothis afterwards even imported into Italy. We ought here to note that the Egyptian religion was older than Babylonian Astrology, and since Sirius rose heliacally about the time of the inundation of the Nile, this star was especially venerated in Egypt from the earliest times; therefore when astrology came west it does not appear to have inspired among the Egyptians (except the Alexandrians) that dread of Sirius, which was spread throughout the Greek and Roman world. The conditions in Egypt were unfavorable to the growth of the idea that Sirius exercised an evil influence, and hence we find astrological doctrines (especially that which assigned the heat of the "Dog Days" to the "influence" of the "burning Sirius") more firmly implanted in the minds of the people north of the Mediterranean, where the climatic conditions favored their propagation.

Some of the authorities cited by M. Lafaye seem worth quoting:

Horapollo: *"Ισις δὲ παρ' ἀρτοῖς (τοῖς Αἰγυπτίοις) ἔστιν ἀστὴρ, Αἰγυπτιστὶ καλούμενος Σῶθις."*

Also *"Αἰγυπτιστὶ καλούμενος Σῶθις, Ἐλληνιστὶ δὲ Αστροκόνων."*

Plutarch: *"οἱ (δὲ) ἕρεις λέγουσιν...τῶν θεῶν...τὰς φυχὰς ἐν οὐρανῷ λάρπειν ἀστρα, καὶ καλεῖσθαι κόνια μὲν τὴν Ἰσιδόν τρέψαντας Ἐλλήνων, διπέρ Αἰγυπτίων δὲ Σῶθις, Ωρίων δὲ τὴν "Ωρον, τὴν δὲ Τοφάνων "Αρκτον."*

And *"Ἄιθιος δὲ Αἰγύπτιων καταγελῶσι μυθολογούντων περὶ τοῦ ὄρογος, ὡς φωνὴν ἀφείνοντος ἡμέρας ἐκείνης καὶ ὥρας ἡς ἐπιτέλλεται τὸ ἀστρον, δὲ Σῶθηρ ἀρτοί, Κόνια δὲ καὶ Σείριον ἡμέρας καλούμενην."*

Also *"τὸν μὲν Ωρίωνα "Ωρον, τοῦ δὲ Κόνια "Ισιδός οερὸν Αἰγύπτιοι νομίζουσιν."*

Library of Photius: *"τὴν Σῶθιν Αἰγύπτιων τὴν Ἰσιν εἶναι θεολογοῦσσαν, οἱ δὲ Ἐλληνες εἰς τὸν Σείριον ἀπάριστοι τοῦτο τὸ ἀστρον, καὶ ὡς Κόνια τὸν Σείριον, ὥπαδὸν Ωρίωνος ὄντα κυνηγετοῦντος, οὗτοι διαζωγραφοῦσσιν."*

In the Decree of Canopus (relative to the reform of the calendar) issued in the ninth year of the reign of Ptolemy III, Buergetes I, (B. C. 238) the Greek translation of the Egyptian text reads:

"τὸ ἀστρον τὸ τῆς Ἰσιδός, ἡ νομίζεται διὰ τῶν οερῶν γραμμάτων νέον ἔτεος εἶναι."

In a hieroglyphic inscription engraved upon a column dedicated to Isis at Nysa in Arabia, the goddess herself is made to affirm her identity with the Dog star:

"Ἐγώ Ἰσις εἰμι...ἡ ἐν τῷ ἀστρῳ τῷ κονὶ ἐπιτέλλοντα."

Therefore it is evident that Isis and Sirius are only different names for the same star, and hence we perceive that the inconsistencies of Eratosthenes and Hyginus have arisen from mere confusion of names.

HORACE.

This poet has left us several allusions to the "Dog Star," but only one of these positively affirms that Sirius was red; the others have reference mainly to the intense heat attending the heliacal rising of the star, but they also imply a fiery appearance.

"Hic in reducta valle Caniculæ
Vitabis æstus." (Ode, XVIII, 17, Bk. I.)

"Te flagrantis atrox hora Caniculæ
Nescit tangere." (Ode. XIII, 9, Bk. III.)

"Seu rubra Canicula findet
Infantes statuas." (Sat. V, 39, Bk. II.)

"Flagrans" implies "burning," but "rubra" makes the redness of the star definite. Horace, it is true, is not an astronomical authority, as has been suggested by those who seek to disbelieve the testimony of the ancients; but can anyone suppose that a poet who enjoyed the learning of Rome in the time of Augustus was ignorant of the appearance of so conspicuous and famous a body as the Dog Star, which he had repeatedly spoken of in his own writings? The manner in which "rubra Canicula" is introduced seems to imply not only that the star was red, but that the color was a matter of universal knowledge.

VIRGIL.

In the Georgics we read:

"Jam rapidus, torrens sitientes Sirius Indos,
Ardebat in cœlo, et medium sol igneus orbem." (Lib. IV, verse 324-6.)

In speaking of the Scorpion Virgil says:

"Ipsi tibi jam brachia contrahit ardens scorpions." (Georgics, Lib. I, verse 34.)

We have seen that Germanicus used "ardenti cum pectore" when alluding to Antares; Virgil's "ardens" certainly refers to the same star. "Ardebat in cœlo" then seems to imply that Sirius presented the appearance of Antares: there is also an illusion to drought in the above passage, and Virgil makes a similar

reference in another place (*Georgics*, Lib. II, verse 353), but no color can be inferred.

Now it seems to me that if Sirius had been white, the ancients would much more naturally have attributed the droughts and other evil "influences" of summer to the great ruddy Antares, which was visible during the hottest months.

MANILLIUS.

The author of the "Poeticon Astronomicon" has left us two references to Sirius which imply a fiery appearance:

"Canis in totum portans incendia mundum."

(verse 17, Lib. V.)

"Canis rabit suo igne."

(verse 208, Lib. V.)

The only other allusion in Manilius implying a ruddy color of any other star is that made to Antares in speaking of the Scorpion:

"Attrahit ardenti fulgentem Scorpion astro."

(verse 268, Lib. I.)

SENECA.

After speaking of fire, lightning, evaporation, and other natural phenomena, Seneca says:

"Nec mirum est, si terræ omnis generis et varia evaporatio est; quum in cœlo quoque non unus appareat color rerum, sed acrior sit Caniculae rubor, Nartis remissior, Jovis nullus, in lucem puram nitore perdueto." (Quaest. Nat. Lib. I, cap. I, § 6.)

This is the deliberate statement, and no accidental allusion, of one of the greatest philosophers of antiquity. Seneca's remarks on the colors of Mars and Jupiter show conclusively that he was well acquainted with the appearance of the planets. This may also be inferred from the attention which he gave to comets and meteors, to solar and lunar halos, and other remarkable phenomena. It is, therefore, practically certain that he had observed Sirius hundreds of times, as any natural philosopher at Rome must necessarily have done.

There is absolutely no reason for supposing Seneca's original language to have been other than what we have quoted. The suggestion that the reading should be "fulgor" instead of "rubor" is too absurd to need refutation. We have, therefore, no alternative but to accept the testimony of Seneca as a fact; and the direct and positive manner in which he says Sirius was

redder than Mars certainly entitles his evidence to the very highest consideration.

COLUMELLA.

In speaking of roses Columella compares their hues to Tyrian purple, the rising sun, Sirius, Mars and Venus (when setting with the evening glow or rising with the dawn):

"Jamque Dionæ is redimitur floribus hortus
 Jam rosa mitescit Sarrano clarior astro.
 Nec tam nubifugi Borea Latonia Phœbe
 Purpureo radiat voltu, nec Sirius ardor
 Sic micat, aut rutilus Pyrois aut ore corusco
 Hesperus, Eoo remeat cum Lucifer ortu."

(De Cultu, Hortorum Lib. X, verse 286.)

The reference to Venus evidently is more concerned with the ruddy glow of the sky at sunset and sunrise than with the color of the planet when high in the heavens; for it is absurd to suppose Columella would compare a rose to a body which is merely bright without any color. The language seems to imply that all the objects enumerated were of about the same color, and that the comparison was suggested by the brilliant colors of roses.

PLINY.

In the *Natural History* a good many astronomical allusions occur, but only three bodies are in any case called "ardens," or "igneus," and these are Sirius, Mars and the rising Sun:

"Suus quidem cuique color est, Saturno candidus,
 Jovi clarus, Marte igneus, Lucifero candens, Vespere fulgens,
 Mercurio radians, Lunæ blandus, Soli, cum oritur, ardens, post
 radians." (Nat. Hist. Lib. II., cap. XVIII.)

In speaking of the Etesias, a wind which blew from the North about the rising of the Dog Star, "ardentissimo tempore," Pliny says:

"Mollire eos creditur, solis vapor geminatus ardore sideris, nec
 ulli ventorum magis stati sunt." (Nat. Hist. Lib. II, cap. XLVII.)

The following allusion to rabies in dogs is of great importance:

"Rabies canum Sirio ardente homini pestifera, ut diximus, ita
 morsis letali aquæ metu." (Nat. Hist. Lib. VIII, cap. LXIII.)

It is worth noting that Pliny in speaking of Canopus does not call it "ardens," but "Sidus ingens et clarum." (Lib. VI, cap. XXIV.)

We now come to some very remarkable evidence confirming the ancient redness of Sirius. Pliny (Nat. Hist. Lib. XVIII, cap. XXIX) mentions the Roman agricultural festivals known as the Robigalia (to avert the rust of the corn), the Floralia (that the blooming fruits might mature) and the Vinalia (a festival consecrated to the vine). All of these festivals were held in May, at which time the Sun began to enter the sign of Taurus, and consequently to approach Sirius. Pliny says the Floralia was instituted in the year of the city 516 (238 B. C.), at the bidding of the oracle of the Sibyl, and it is certain that it continued down to the time of the Christian Emperors.

Now, Ovid speaks of the sacrifice of dogs to the Dog Star made at these festivals:

"Est canis, Icarium dicunt, quo sidere moto
Tosta sitit tellus, praecipiturque seges.
Pro cane sidero canis hic imponitur aræ:
Et, quare pereat, nil nisi nomen habet."
(Fastorum, Lib. IV, 939.)

But the most trustworthy evidence regarding the sacrifices attending the celebration of the Floralia is to be obtained from the grammarian Festus, who probably flourished in the time of the Antonines.

SEXTUS POMPEIUS FESTUS.

The title of this author's work is "Sexti Pompei Festi de Verborum Significatu quæ supersunt cum Pauli Epitomæ," (edition of AEmilius Thewrewk, Berlin, 1890.)

Under the word "Catularia" we read:

"Catularia porta Romæ dicta est, quia non longe ab ea ad placendum Caniculæ sidus frugibus inimicum rufæ canes immolabantur, ut fruges florescentes ad maturitatem perducerentur."

(Word, Catularia p. 31.)

In the "Fragmenta" Festus says:

"Rutilæ canes, id est non procul a rubro colore, immolantur, ut ait Ateius Capito Canario Sacrificio pro frugibus deprecandæ servitæ causa sideris Caniculæ." (p. 396.)

Thus it is clear that at the Floralia ruddy dogs were sacrificed "ad placandum Caniculæ sidus;" why ruddy dogs rather than dogs of any other color? There is, I think, only one explanation of this remarkable pagan rite, and that is that the star was red

and that dogs of the same color (non procul a rubro colore) were demanded to satisfy the ruddy Dog Star, and ward off its evil "influences," so that the blooming fruits might not suffer blight when the fiery Sirius came into conjunction with the Sun, but (the "angry" star being appeased) be brought to full maturity. It must be remembered that it was a very common belief among the ancients that stars were deities demanding special propitiation. It is difficult to imagine a more incontestible proof of the ancient redness of Sirius than that furnished by a wide-spread pagan rite extending over centuries and celebrated annually with the greatest hilarity and splendor. The annual sacrifice of ruddy dogs to Sirius must have made the Dog Star very well known to everybody at Rome, and this is what we should infer to have been the fact from the frequency with which the star is mentioned by classic authors. The existence of such a religious rite also makes it impossible that learned men like Cicero, Seneca, Horace, and Pliny can have been ignorant of the color of Sirius.

PTOLEMY.

In the Catalogue (7th and 8th books of the Almagest) Ptolemy calls Arcturus, Aldebaran, Pollux, Betelgeux, Antares and Sirius ὑπόχρημα, "fiery red." All of these stars except Sirius are still red or reddish, and there are no other conspicuous stars so highly colored as these. Ptolemy therefore did not overlook the red color of the most conspicuous stars, and on this account, as well as on account of the genius displayed in his immortal Almagest, he is by far the greatest authority of antiquity for the appearance of a heavenly body. His note on Sirius in enumerating the stars in the constellation Κύων is this:

"εἰς τῷ στόματι λαμπρότατος Κυλούρενος Κύων καὶ ὑπόχρημα"

(edition of Halme and Delambre, Vol. II. p. 72).

The Basel manuscript reads "Κύων ὑπόχρημα instead of "Κύων καὶ ὑπόχρημα," and this reading has been adopted by Mr. Frances Baily in his edition of Ptolemy's Catalogue, published in the Memoirs of the Royal Astronomical Society, vol. XIII. Since, however, the meaning remains unchanged, it is not a matter of any importance which reading we accept. It has been asserted by Mr. W. T. Lynn (*Observatory*, vol. X, p. 104) that the note on Sirius is "somewhat peculiar;" but after comparing it with Ptolemy's notes on other red and bright stars I fail to discover anything suspicious about the record he has left us. There is only one other convenient form in which the note could have been written:—

“οὐ ἐν τῷ στόματι λαρπράτατος καὶ ὑπόκτημος καλοίηνος Κύων.”

Adopting, however, the reading given by Baily, the language of Ptolemy in regard to Sirius is exactly similar to that used for Arcturus. Professor Schjellerup in the introduction to his admirable translation of Al Sûfi's “Description of the Fixed Stars,” was the first to question the genuineness of the language of the Almagest in regard to Sirius; Mr. Lynn and Miss A. M. Clerke (“System of the Stars,” p. 146) have followed Professor Schjellerup in explaining Ptolemy's “Κύων καὶ ὑπόκτημος” as a transcriber's error for “Κύων καὶ Σείρων,” an explanation *a priori* very improbable on account of the magnitude of the error postulated, and in fact without the slightest foundation, as we shall now proceed to show.

Professor Schjellerup believed he had discovered in Albategnius' “*De numero Stellarum*”—usually known as “*De Scientia Stellarum Fixarum*”—a statement that Ptolemy mentioned only five red stars, and from this he concluded that Sirius was not classed as a red star in the Arabian versions of Ptolemy's Almagest. Plato Tibertinus published in one volume at Nuremberg in 1537, a Latin translation (which is so bad that Delambre calls it “semi-barbaric”) of a part of Alfraganus' “*Elementa Astronomica*” and Albategnius' “*De numero Stellarum*” under the name of “*De motu Stellarum*,” but the work is usually known as “*De Scientia Stellarum*.” Now, in the part of this work taken from Alfraganus where the stars catalogued by Ptolemy are enumerated, we read “5 rubaeæ,” but the reading should be “5 nebulosæ,” as we see by referring to the good edition of Alfraganus published at Frankfort (in 1590 and 1618) by Jacob Christmann, and to the still better translation (with Latin and Arabic text) published by the illustrious Arabic scholar, Jacob Golius, at Amsterdam, in 1668. In Tibertinus' work the chapter in which the passage occurs is numbered XIX, and likewise in Golius' translation, but in Christmann's the number is XXII.

The correct reading is therefore “5 nebulosæ,” which agrees with what Ptolemy has given at the end of his catalogue, where he sums up the number of stars of the different magnitudes and also those classed as “nebulous” and “obscure,” but gives no summary of those classed as ὑπόκτημος. Now this summary of Ptolemy is copied by both Alfraganus and Albategnius *verbatim et literatim* without any addition or change whatever. Therefore I do not hesitate to venture the opinion that no Arabian Astronomer ever went to the trouble to count up Ptolemy's red

stars. This servile repetition of Ptolemy's summary without adding to it the number of stars classed as red is another proof of the proverbial sterility of the Arabian genius.

I have very carefully examined Albategnius' "De numero Stellarum" (both Tibertinus' edition, and that of Ugullottus, which appeared at Bologne in 1645), as well as Alfraganus' "Elementa Astronomica" (editions of Christmann and Golius), with the following results:—

(1). Albategnius and Alfraganus are both absolutely silent concerning Ptolemy's observations of red stars. (And the same is true of Al Sûfi and Ulugh Beigh, as we shall presently see).

(2). Albategnius himself does not note the color of any star; but Alfraganus speaks incidentally of the color of Antares, Pollux and Aldebaran.

Therefore it is evident that Professor Schjellerup was misled by the false translation of Plato Tibertinus, and there is no authority for the statement that Albategnius gave the number of Ptolemy's red stars as five. Alfraganus and Albategnius both flourished about the end of the 9th century, and are among the most important authorities dating from the era of Saracen splendor. As respects the colors of the stars, however, the authority of Al Sûfi, who flourished about the middle of the 10th century, is greater, and indeed the greatest of all the Arabian Astronomers. His "Description of the Fixed Stars" is founded upon the catalogue of Ptolemy, and the name of Ptolemy is often mentioned in locating the stars of a constellation in their respective places, *but Sûfi never, in a single instance, alludes to Ptolemy's observations of the colors of the stars.* Al Sûfi noted as red the following stars: Aldebaran, Arcturus, Antares, Betelgeux, Pollux, *a* Hydræ, and *—mirabile dictu—*Algol! Nothing is said of the color of Sirius, and after calling it "very brilliant," and locating it in the mouth of the Dog, Sûfi proceeds to relate an Arabian fable in which Sirius and Canopus are spoken of as sisters. This fable would seem to imply that Sirius and Canopus could not have had conspicuously different colors in the 10th century; they appear now to be exactly the same color, as near as I could determine by naked-eye observation at Cairo, Egypt (March 15th, 1891.)

Al Sûfi therefore noted the colors of all of Ptolemy's red stars except Sirius, and added to the list *a* Hydræ, which is now reddish, and Algol which is perfectly white. Sûfi and Schmidt (on one occasion at Athens in 1841) are the sole authorities for the redness of Algol; it remains, therefore, uncertain whether Algol

has changed its color, or is subject to temporary suffusion of redness, or whether the two observers have in some way been deceived. The fact that Sūfi says nothing of Ptolemy's observations of red stars, and that he noted the color of *a Hydræ* and Algol, would lead one to conclude that Sūfi's notes were the result of his own incidental observations; there is no reason to suppose he devoted especial attention to the colors of the stars.

Ulugh Beigh in his catalogue (edition of Baily, Mem. Roy. Ast. Soc., vol. XIII) notes the colors of Antares, Aldeberan, Betelegeux and Pollux; but overlooks the color of Arcturus and *a Hydræ*, and says nothing of the color of Algol or Sirius. In Tycho Brahe's catalogue Antares alone is noted as ruddy; Sirius is called "splendidissimo." Alfraganus, Albategnius, Al Sūfi and Ulugh Beigh are the only important Arabian authorities on the appearance of the fixed stars. Therefore, since all of these are silent concerning the color of Sirius, it is very unlikely that any information will ever be obtained from lesser Saracen authorities.

We see therefore that the Arabians throw no light whatever upon Ptolemy's record of the color of Sirius; and we have also seen that there is absolutely no ground for supposing an error to have crept into our copies of the Almagest. Therefore there is every reason to suppose that Ptolemy himself classed Sirius as fiery red. That he can have mistaken the color of this star in the steady atmosphere of Egypt is quite incredible. For Sirius attained a high elevation in passing the meridian, and Ptolemy was not deceived by atmospheric scintillation, as is proved by the fact that he assigned no colors to bright stars lying much further south, such as *a Centauri* and *Canopus*. Moreover the present scintillation of Sirius (as I have found by careful observation) is exceedingly blue with scarcely a trace of red; and this is a *general reason* why the ancients can not have been deceived by atmospheric effects upon the light of the star; for had they assigned the color from scintillation such as it now shows, the star would certainly have been classed as blue.

CONCLUSION.

We have seen that the highest authorities of antiquity affirm the redness of Sirius, and that there is no authority who affirms that the star was white. We have also seen that the ancients distinguished between the red and white stars and that the distinctions were correctly made. It has been shown that the whole ancient world ascribed the intense heat of the "Dog Days" to the "influence" of the "burning Dog Star," and that evil

“influences” were usually supposed to proceed from bodies presenting a fiery (“angry”) appearance, and “salutary” influences from those which shine with a clear brilliant light. Moreover, at the celebration of the *Floralia*, when the Sun was drawing near to Sirius, we have seen that ruddy dogs were sacrificed “ad placandum *Caniculae sidus*.” Wherefore, from this many-sided and overwhelming testimony it incontestibly follows that in the beginning of our era (and perhaps during countless centuries antecedent thereto) Sirius shone with a ruddy light; and since Seneca says explicitly that the star was redder than Mars, and there is every reason to believe his statement, we may conclude that the Dog Star was then the reddest body in the sky, not even excepting the ruddy *Antares*.

The following is the comparative evidence for the ancient redness of the two stars:

Author.	Sirius.	Antares.
1. Ptolemy	“ <i>ὑπόχιρός</i> ”	“ <i>ὑπόχιρός</i> .”
2. Geminus	“ <i>πόρπυρος</i> ” (multitude ἀριθμοῦ)	
3. Seneca	“ <i>Acrior sit Caniculae ru- bor, Martis remissior.</i> ”	
4. Pliny	“ <i>Ardore Sideris</i> ” and “ <i>Sirio ardente</i> ” (like Mars and rising Sun).	
5. Cicero	“ <i>rutilo cum lumine.</i> ”	
6. Germanicus.	“ <i>Cursu rutili</i> ”	“ <i>ardenti cum pectore</i> ”
7. Aratus.....	“ <i>ποτικίος.</i> ”	
8. Horace	“ <i>rubra Canicula.</i> ”	
9. Festus	“ <i>Rutilæ Canes immola- bantur ad placandum Caniculae Sidus.</i> ”	
10. Columella....	“ <i>Sirius ardor.</i> ”	
11. Hesoid.....	“ <i>Σείριος ἄρει.</i> ”	
12. Virgil.....	“ <i>Ardebat in cœlo.</i> ”	“ <i>ardens</i> ”
13. Manilius.....	“ <i>rabit suo igne.</i> ”	“ <i>ardenti astro</i> ”
14. Theon.....	“ <i>ποτικίος.</i> ”	
15. Ap. Rhodius.	“ <i>Σείριος ἔφεγε.</i> ”	
16. Euripides.....	“ <i>πυρὸς φλογέας.</i> ”	
17. Avienus.....	“ <i>multus rubor.</i> ”	
18. Homer.....	“ <i>φέρει πολλὸν πυρετὸν,</i> ” and “ <i>χαλκίς,</i> ” also “ <i>ἀχάματον πῦρ, ἀστέρ̄ ὁπωρινῷ ἐναλίγκιον.</i> ”	

From this investigation it follows that Sirius has become white since the time of the Roman emperors, and, if we may trust Theon and Avienus, perhaps since the end of the fourth century. That the star was not conspicuously red in the tenth century may be inferred from the silence of Al Sūfi; but farther than that can not at present be determined. The star may have changed color very suddenly, or its redness may have gradually faded with the centuries and disappeared slowly like the ancient civilization. There is practically no record of the heavens from the time of Theon to Al Sūfi; and therefore the rapidity of the change can not be ascertained. In modern times the star has always been seen white, and therefore there is no suspicion that the color changes periodically. The redness of a star's light depends without doubt mainly upon the selective absorption in its own atmosphere; therefore the natural explanation of this change of color would seem to be a change in the atmosphere by which Sirius is surrounded. This might take place solely from the secular contraction of the mass, and when we remember the enormous rate at which Sirius is losing radiant energy, an explanation of this kind seems very likely to be correct. The emission of heat and light is at least one hundred fold that of our Sun, and therefore two hundred thousand years of solar radiation will scarcely equal a radiation of two thousand years in Sirius. And we are certainly far from being able to affirm that our Sun was not red two thousand centuries ago. The change in the color of Sirius during the last 2,000 years is not then so very remarkable, as it could result from purely natural causes; but we shall not in this paper attempt to assign the cause of the change. It is sufficient for the present to establish the fact.

It only remains to add that in the foregoing investigation the authorities cited have been examined with the most scrupulous care, and therefore I do not think anything of any importance can have been overlooked. From Censorinus, Varro, Cato, Aristotle (*Treatise on the Heavens*), Plato, Sophocles, Æschylus, Pindar, Tacitus, Polybius, Livy, Manetho and Empedocles, I have not been able to obtain any information of any value. There are some other classic authors from whom information might be obtained, and it would also be interesting to extend the inquiry to the Egyptian, Chaldean, Assyrian, Indian and Chinese writers, but it is doubtful whether much would be gained. The foregoing testimony of the Greeks and Romans seems to have settled the question already, and time employed in this manner would perhaps be largely wasted.

Since, therefore, Sirius was formerly red, and is now white, it follows that some of the red stars become white in the course of ages, and this we may perhaps infer to be the general law of color in celestial evolution. Whilst, therefore, I think we may conclude that red stars in time become white, it does not follow that all white stars have formerly been red; for if this were the case the sidereal system at some past time must perhaps have been as red as it is now white, which is very improbable. It would be a matter of great scientific interest to determine the exact shade of all the important colored stars now visible, so that changes which might hereafter take place could easily be recognized, and thus the order of color evolution determined with greater certainty. It is always possible (though very improbable) that an individual change of color may result from some exceptional circumstance, and therefore it is desirable to establish as early as possible a considerable number of changes, so that the effects of chance may be eliminated, and the phenomena referred to their true physical cause.

ROYAL OBSERVATORY, Berlin, Jan. 28, 1892.

OBSERVATIONS AND PHOTOGRAPHS OF SWIFT'S COMET OF
MARCH 6, 1892.*

E. E. BARNARD.

I have observed Swift's new comet on every available occasion since March 7.

Unfortunately a prolonged cloudy spell prevented many observations during March and especially during the latter half of the month; no opportunity occurring to observe the comet until the morning of April 4 when the sky cleared after midnight.

At this observation, on the morning of the 4th, the remarkable growth of the comet was at once apparent. At the previous observations, March 7, 8, 9 and 15th, though distinctly visible to the naked eye as a large, hazy star of the 5th or 6th magnitude, no tail whatever was visible, and only an incipient one could be seen with the telescope.

On the morning of April 4 the head was slightly less than the 3d magnitude. The tail was fully twenty degrees long and straight and slender. Careful sketches were made of the position of the tail as seen by the naked eye and of the head and tail

* Communicated by the author.

as seen in the 12-inch. The head was undeveloped and round with a bright nucleus which showed indications of fans on the sunward side. The telescopic view of the tail showed it to consist of two branches, well defined on their outside edges. Scarcely any nebulosity was visible between these two tails. The northern tail prolonged would have passed through the nucleus. There was positively no trace of a third branch.

On the morning of the 5th, I made a photograph of the comet with the 6-inch Willard lens strapped on to the 6½-inch equatorial. The nucleus was followed, and an exposure of one hour was given. During about three-fourths of the exposure, the comet was covered with haze and clouds.

This photograph showed a remarkable state of affairs. There were now three main branches to the tail—a new one having sprung out between the two which were seen on the previous morning. Each of these branches was, in turn, separated into several others until at least a dozen could be counted. The comet's head was about 19' in diameter and the width of the tails where they joined the head, about 13'. The north tail—a narrow ray—was 2° long. The middle tail ran off the plate at a distance of 8° from the nucleus.

At a distance of two degrees from the head, along the northern side of the middle tail, a sudden bend southward occurs, from whence the tail continues. Springing from the north preceding portion of the head, two fine, dark thread-like lines are shown. These appear to be darker than the sky anywhere on the plate, though they may be simply due to contrast, as there is a faint strip of nebulosity between them. Some thread-like strips of nebulosity emanate from the head on both sides and stream back in the direction of the tail.

On the morning of the 6th, the eastern sky was densely clouded and the comet did not get out of the clouds until after 4 hours. An exposure of half an hour was given through a hazy sky and dawn. This plate is defective, but enough is shown to mark a great change in the tail. The short northern branch had wholly disappeared and the two others had blended together more or less to form a single flat train very narrow where it joined the head. There are brushes of matter extending on both sides of the head in a preceding direction for a few minutes of arc. The tail was much broken by longitudinal stripes.

On the morning of the 7th perhaps the most successful picture of the series was made. This exposure extended from 3^h 30^m to 4^h 35^m. The sky was free from clouds, but moonlight and dawn interfered. The most remarkable changes are shown on this plate. The southern component, which was the brightest on the

5th, had become diffused and fainter, while the middle tail was very bright and broad. Its southern side, which was the best defined, was wavy in numerous places—the tail appearing as if disturbing currents were flowing at right angles to it. At $42'$ from the head the tail made an abrupt bend towards the south as if its current was deflected by some obstacle. In the densest portion of the tail at the point of deflection, is a couple of dark holes—similar to those seen in some of the nebulae. The middle portion of the tail is brighter and looks like crumpled silk in places. The width of the tail at 2° from the head is $54'$.

On the morning of the 8th in moonlight and dawn, an exposure of one hour was given. This plate was developed with difficulty as the strong moonlight and dawn had fogged it somewhat, and the resulting image is necessarily weak but clearly defined. The tail is traceable for upwards of 10° , where it leaves the plate. The most remarkable changes had occurred since the preceding morning. Near the head the tail was split up into six different branches. The northern being no longer the main branch; it seems to have faded out while the southern branch is the most prominent and shows a remarkable and unique phenomenon. At $1^\circ 42'$ back of the head there is a projecting lump-like mass from the south side of the tail. This leaves the tail at an angle of about 115° , and extending out for a space of about $15'$. From this the tail again continues its course. A lesser projection is seen on the north side of this same branch. At one degree back of the head there is a sharp bend in this tail towards the north, exactly similar to the bend which was visible in the north tail on the 7th.

Some of these remarkable changes in the relative brightness of the component parts of the tail, etc., as shown on the photographs of different mornings, would almost suggest a rotation of the tail on an axis through the nucleus. Unfortunately cloudy weather and moonlight have prevented anything definite in explanation of these changes.

This comet, with a head of the 3rd magnitude, and a rather strongly marked tail twenty degrees in length, is the largest comet visible in the northern hemisphere since the great comet of 1882. It is the first large comet that the photographic plate has been applied to successfully since that of 1882, and the phenomena shown and the exceedingly rapid changes recorded, would seem to show that this is one of the most remarkable comets we have yet had.

I secured a number of sketches of the position of the tail among the stars which will be valuable in connection with the photographs, in a study of the physical structure of this remarkable comet.

For the inspection of the editor of this journal I send two glass positives from the negatives of April 4 and 6. From a lack of the proper transparency plates, these are not as good positives as I would wish, and therefore are not suitable for reproduction here. It is proposed later to make a thorough discussion of these photographs.

Mt. HAMILTON 1892, April 12.

ASTRO-PHYSICS.

ON THE SPECTRA AND PROPER MOTIONS OF STARS.*

W. H. S. MONCK.

I have more than once called attention to the relation between the spectra of stars and their proper motions, and in the February No. of ASTRONOMY AND ASTRO-PHYSICS, I suggested that the broad distinction between Sirian and Solar stars was insufficient for the purpose, and that it would be necessary to take into consideration the minuter distinctions given in the *Draper Catalogue*. I now send the result of applying this distinction to stars of the types designated B and F in the *Draper Catalogue*, and I think the difference will be found rather startling. I did not carry the comparison below the 5th magnitude (according to the *Harvard Photometry*) because Professor Pickering admits that the classification of the spectra of the fainter stars in the *Draper Catalogue* is not to be relied on in its full details. The sub-classes B and F stand nearly at opposite extremities of the scale as regards proper motion, and the average motion for the latter sub-class is so large as to suggest that the Sun forms one of a cluster of stars belonging chiefly to this sub-class or to the sub-class E which, in many respects, resembles it. Other grounds might be urged in support of this hypothesis, but in the present article, I confine myself to facts. The magnitudes are taken from the *Harvard Photometry*, and the Proper Motions from Mr. Main's Catalogue.

STARS WITH SPECTRUM B.

Proper Motion.		Proper Motion.					
Star.	Magn.	Parallel.	N. P. D.	Star.	Magn.	Parallel.	N. P. D.
γ Orionis	1.86	0.03	0.04	54 Andromedæ	4.24	- 0.01	0.03
β Canis Majoris	2.01	0.01	0.02	μ^1 Bootis	4.38	- 0.17	- 0.09
σ Sagittarii	2.30	0.00	0.08	τ Tauri	4.40	0.00	0.02
δ Orionis	2.36	0.02	0.04	ν Andromedæ	4.42	- 0.03	0.01
η Canis Majoris	2.41	- 0.05	- 0.01	v Cygni	4.44	0.00	0.01
δ Scorpii	2.52	- 0.01	0.01	π^2 Cygni	4.44	0.00	0.02
β Scorpii	2.91	- 0.03	0.02	ω Orionis	4.50	0.03	0.00
ι Orionis	2.97	0.02	0.01	ξ Ophiuchi	4.51	0.24	0.21
ζ Canis Majoris	3.01	0.03	- 0.02	λ Persei	4.54	- 0.02	0.05
π Scorpii	3.08	- 0.04	0.04	6 Lacertæ	4.57	- 0.04	0.00
θ Ophiuchi	3.44	- 0.04	- 0.02	57 Cygni	4.59	- 0.01	0.00
λ Tauri	3.59	- 0.03	0.02	α Orionis	4.65	0.02	0.02
ι Herculis	3.92	0.15	- 0.01	48 Libræ	4.80	- 0.03	0.10
π^2 Orionis	3.98	0.03	0.01	α Tauri	4.82	- 0.01	0.01
67 Ophiuchi	4.02	0.00	0.03	π^1 Cygni	4.87	- 0.05	0.01
δ Ceti	4.13	0.05	0.03	u Herculis	4.91	- 0.04	0.00
π^2 Scorpii	4.17	- 0.03	0.03	2 Cygni	4.93	0.01	- 0.05
γ Cassiopeiae	4.18	- 0.01	- 0.01				

* Communicated by the author.

STARS WITH SPECTRUM F.

Star.	Magn.	Proper Motion.			Star.	Magn.	Proper Motion.		
		Parallel.	"	N. P. D.			Parallel.	"	N. P. D.
Capella	0.18	0.08	0.43		42 Comæ	4.38	-0.44	-0.13	
Rigel	0.32	-0.02	0.02		43 Comæ	4.38	-0.79	-0.89	
Procyon	0.46	-0.72	1.08		μ Cygni	4.39	0.21	0.26	
α Persei	1.94	0.02	0.05		π^1 Pegasi	4.41	-0.04	0.05	
Polaris	2.15	0.03	0.00		π^2 Pegasi	4.41	-0.01	0.00	
β Cassiopeiae	2.42	0.50	0.19		τ Bootis	4.50	-0.48	0.05	
α Leporis	2.67	0.01	0.00		ψ Draconis	4.52	0.00	0.27	
γ Virginis	2.84	-0.56	0.05		93 Leonis	4.55	-0.20	0.00	
π Sagittarii	3.11	-0.06	0.03		ℓ^1 Cygni	4.57	-0.05	0.01	
π Orionis	3.33	0.49	0.01		ν Pegasi	4.57	0.18	-0.03	
ξ Geminorum	3.36	-0.10	0.22		π Aquarii	4.59	0.00	0.01	
α Trianguli	3.59	0.00	0.23		ψ Herculis	4.63	-0.03	-0.01	
η Cassiopeiae	3.64	1.08	0.49		χ^1 Orionis	4.65	-0.23	0.10	
β Delphini	3.74	0.07	0.04		ℓ^2 Cygni	4.65	-0.02	-0.15	
η Leporis	3.74	-0.03	-0.14		ν Sagittarii	4.67	-0.03	0.05	
γ Leporis	3.76	-0.32	0.37		20 Ophiuchi	4.68	0.06	0.08	
12 Eridani	3.77	0.33	-0.62		ξ^1 Cancri	4.72	0.06	0.11	
ζ Aquarii	3.81	0.14	-0.03		χ Leonis	4.74	-0.36	0.08	
τ Cygni	3.94	0.16	-0.47		A Scorpis	4.74	-0.04	0.01	
ι Pegasi	3.99	0.29	-0.02		b Scorpis	4.79	-0.07	0.02	
β^2 Cephei	4.00	0.02	0.02		δ^2 Ursæ Majoris	4.79	-0.03	0.11	
μ Sagittarii	4.08	-0.06	0.01		ω Andromedæ	4.80	0.33	0.11	
α^1 Eridani	4.10	-0.03	-0.07		ν Aquilæ	4.80	0.00	-0.04	
ω Piscium	4.16	0.15	0.13		ℓ Bootis	4.84	0.00	0.05	
10 Ursæ Majoris	4.19	-0.44	0.27		36 Ursæ Majoris	4.89	-0.11	-0.01	
ι Virginis	4.23	0.02	0.41		ι Bootis	4.90	-0.45	0.02	
50 Andromedæ	4.24	-0.18	-0.39		τ^1 Hydræ	4.94	0.11	0.03	
δ Bootis	4.25	-0.26	0.41		40 Leonis	4.95	-0.27	0.20	
τ Piscium	4.28	0.37	0.45		λ Aurigæ	4.95	0.49	0.70	
8 Canum Ven.	4.30	-0.77	-0.30		36 Draconis	4.98	0.34	-0.01	
ψ Capricorni	4.30	-0.09	0.17		58 Ophiuchi	4.98	-0.14	-0.04	
λ Serpentis	4.35	-0.19	0.04						

This list will, I think, be found to be pretty nearly complete, and, at all events, it has been impartially selected. The high proper motions of the stars of the F type continue below the fifth magnitude as far as the *Draper Catalogue* continues to distinguish them. Several of the stars in the above list have their spectrum marked with a (?), and I suspect that a more accurate determination of their spectra would remove them from the F class to some other; for it is often with the slow-moving stars that the query occurs. There are, however, some bright stars of this class whose spectra do not appear to be open to doubt, but whose proper motions are notwithstanding very small. Whether these stars are really distant, or whether their proper motions are neutralized by the motion of the solar system in space remains to be ascertained. It is not probable that stars with any particular class of spectrum are to be found near the Sun *only*, but there is no improbability in supposing that a particular type preponderates among our own nearest neighbors. In any case I think the

necessity of considering the spectrum in all questions connected with the proper motions of stars (such as the determination of the Sun's motion in space), will clearly appear.

DUBLIN, Ireland.

THE MOTION OF NOVA AURIGÆ IN THE LINE OF SIGHT.*

H. C. VOGEL.

Although the spectroscopic observations of the Nova in Auriga are not yet concluded—since the star will probably continue visible for some time—I consider it of importance, in the interest of the subject, to communicate my observations made hitherto, and the conclusions drawn therefrom, even though the latter should not in the future be confirmed in all points.

Concerning, first, the direct spectroscopic observations, I have, on February 20, observed the Nova with a compound spectroscope of a dispersion sufficient just to show the nickel line between the D lines. The hydrogen lines C, F, and $H\gamma$ appeared bright. Their identification was easy by means of a hydrogen tube in front of the slit. These three lines did not exactly coincide with the lines of the comparison spectrum, but were displaced considerably toward the red, without, however, separating completely from the artificial lines since they were very broad. The continuous spectrum appeared faint, owing to the comparatively high dispersion; and with certainty only the dark broad F line was recognizable, situated toward the more refrangible side, distinctly separated from the bright line in the spectrum.

Between C and F a large number of bright lines could be seen, but most of them were too faint to be fixed with certainty. In the case of two brighter lines near F, Mr. Frost, who assisted in the observations, and myself, succeeded in making very certain wave-length determinations; we found $492.5\mu\mu$ for the fainter of the two lines, which appeared broad and fuzzy on both edges, and $501.6\mu\mu$ for the brighter line. The limit of error is to be taken at about $\pm .3\mu\mu$, and it results from the observation with certainty that the brighter line is *not* identical with the double line of the air spectrum or with the brightest line of the nebulae, and still less the other with the second nebular line. From Young's list of lines most frequent in the chromosphere, it follows that near F only the two groups of lines, 501.87, 501.59, and

* *Nature*, March 24, 1892.

493.44, 492.43, 492.24, 491.92, frequently appear bright. There is no doubt that both lines in the spectrum of the Nova are chromosphere lines, and this result appears to me of great importance, in so far as it is made probable that the line observed in Nova Cygni (1876)—W. L. $500\mu\mu \pm 1\mu\mu$ —which, during the gradual fading of the star, alone remained, was a chromosphere line, and not the nebular line.

Further both Mr. Frost and myself probably saw the magnesium lines, certainly the sodium lines bright, as also two lines between *b* and *D*, one of which was probably the well-known chromosphere line W. L. 531.72, also observed in Nova Cygni. By direct comparison with the hydrocarbon spectrum, the brightest band of which nearly coincides with the *b* group, and with the sodium flame, *b* and *D* were identified. Mr. Frost could see a displacement of the *D* lines in the star spectrum with respect to the comparison spectrum. There was no indication of hydrocarbon bands in the spectrum of the Nova.

Up to the present eleven mostly very good spectrographic photographs have been taken; they were obtained by means of a small spectrograph connected to the photographic refractor of 34 cm. aperture. The dispersion is only small, but in the small spectrum of 10 mm. length, extending from *F* to *H*, much detail is discernible. The illuminating power of the apparatus is so great, in spite of the narrow slit employed, that even now an exposure of forty minutes is sufficient to obtain an image suitable for measurement. The bright hydrogen lines *F*, $H\gamma$, *h*, *H*, and the calcium line, H_2 , are very broad; and, as already announced, the corresponding dark lines of a second spectrum are displaced with respect to the bright lines toward the violet, and in spite of the breadth of the latter, are almost entirely separated. There are also some of the hydrogen lines in the ultra-violet visible, but they are too faint for any approximately certain observation.

In the last few days the spectrum has changed, inasmuch as in the broad bright lines $H\gamma$, *h*, *H*, and H_2 (*F* is only traced on plates which are over-exposed for the middle of the photographic spectrum), two maxima of intensity are plainly discernible, and, as in each of the corresponding dark lines, a narrow bright line has appeared. From the measurements, a connection between these and the hydrogen lines appears beyond doubt, and it is not improbable that these linear brightenings in the broad dark lines indicate eruptions of gases from the interior of the body possessing the continuous spectrum with the dark absorption lines. Such brightenings are occasionally seen in the spectra of Sun-

spots. On this supposition, the fine bright lines would indicate very nearly the middle of the dark lines.

The appearance of two maxima of intensity in the broad bright lines admits of the conclusion that two bodies with different motions possess spectra with bright lines, and that therefore the spectrum of the Nova consists of at least three spectra superposed, from the measurement of which, in connection with the comparison spectra of β Aurigæ or β Tauri on the same plate, the relative motions of the three supposed bodies, as well as their motions with respect to the earth, can be determined. Denoting the body with the dark-line spectrum by a , the two others with bright-line spectra by b and c , measurements by Dr. Scheiner and myself have given the following results:

$$a - \frac{1}{2}(b + c) = 120 \text{ miles,}^*$$

$$b - c = 70 \text{ miles;}$$

and further with respect to the earth—

$$a = -90 \text{ miles, } b = -5, c = +65 \text{ miles.}$$

This result is still very uncertain, and must be regarded as quite preliminary, for it is evident that with the small size of the spectra the accuracy cannot be pushed very far—a displacement of .01 mm. corresponds, for instance, to a motion of 8 to 12 miles, according to the situation of the line in the spectrum—and that the size of the silver grain in the photographs can exert a very marked influence on the measurements.

In the photographic spectrum of the Nova, besides the broad lines mentioned, several more bright and mostly very broad lines can be seen, whose wave-lengths I intend to communicate later on.

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SOME RECENT STUDIES ON THE SOLAR SPECTRUM.[†]

A. L. CORTIE.

Until the middle of this century the term Physical Astronomy, as distinguished from Observational Astronomy, was usually applied to those investigations of the mathematicians of the mechanics of the celestial sphere, by which they triumphantly vindicated the truth of Newton's theory of gravitation, as giving the only sufficient explanation of the motions of the heavenly bodies. It then came to be used of all such observations and

* = about 540 English miles.—*Tr.* † *The Month*, August 1891.

deductions therefrom, as depend upon or are explainable by the principles of chemistry and physics. And now this latter branch of astronomy, sometimes called the New Astronomy, which has made gigantic strides since the invention of the spectroscope and our greater knowledge of the action of light, has almost entirely usurped to itself the title of Physical Astronomy, leaving to the older science the name of Mathematical Astronomy. In the following pages it will be our endeavor to give a brief sketch of the recent progress which has been made in but one line of research in this newer science, and to record the successes of the last few years. We have prefaced and interspersed our review with such remarks as are deemed necessary for the clearer understanding of a technical subject by those whose reading has mostly lain in other directions.

The first map of the solar spectrum, which could pretend to give a picture of the chief dark lines, or images of the slit of the spectroscope caused by the absorption of the solar atmosphere, was drawn in the year 1814-15 by the celebrated Fraunhofer. He also proved, by observing the spectra of the brighter stars and noting their discrepancies from the solar spectrum, that these dark lines, whatever might be their true explanation, were not solely due to the action on the rays of the Sun of the Earth's atmosphere. But he went no further. In 1849, Foucault, while experimenting with the spectrum formed by the carbon points of the voltaic arc, observed the coincidence of two bright yellow lines due to the metal sodium, with the black double of the solar spectrum called D by Fraunhofer. And not only this; for he was struck by the appearance of the D lines when the spectrum of the glowing vapors was superposed upon them, which, instead of becoming less dark as would have been naturally expected, were seen to be darker than usual. The observation of this seeming anomaly was a second great step in advance. The theoretical explanation of this appearance was first enunciated, though not published, in 1852 by Professor, now Sir George, Stokes, arguing from the analogy of the absorption of sound waves by a suitable medium. If the explanation was correct, it followed that the spectroscope had, despite the oft-quoted dictum of Comte uttered barely a decade before, proved beyond doubt the existence of sodium in the Sun. In 1859 a German physicist, Kirchhoff by name, performed in his laboratory the classical experiment of reversing the sodium or D lines; reversing, that is, by passing the continuous spectrum formed by the carbon points through hot

sodium vapors, he caused the D lines to be alone selected in the process of filtration for absorption, and to appear dark instead of bright on the screen. The arc being taken to represent the Sun, and its continuous spectrum the background of the solar spectrum, the sodium vapors would stand in place of a burning atmosphere around our luminary, and hence the lines of sodium, or indeed of any other metal, being found as dark in the solar spectrum, would indicate the presence of the vapors of that metal in the Sun's atmosphere. This one experiment may truly be said to have created a new branch of astronomical physics, a branch which has already been prolific of most marvelous results, and which is full of promise of greater marvels yet to come. For it is wonderful that stars or suns so immeasurably distant, that the light traveling from them at the rate of 186,000 miles a second, consuming in some cases half a century or more to reach our planet, are by means of the spectroscope analyzed, and the materials out of which they are built up, catalogued with almost as great an ease as the chemist tests the terrestrial matters in his laboratory.

Confining our attention, however, to the solar spectrum, it is evident that the first requisite, before we can hope to unravel any of its hidden teachings, is that we should possess as perfect a map as possible of all its multitude of lines. Kirchhoff was not slow to perceive this necessity, and in conjunction with Bunsen he commenced and nearly finished a beautiful map of the solar spectrum. It was published in 1861, having been completed by the labors of Hofmann. The spectroscope employed consisted of four prisms of flint glass, and the patient toil required for the drawing of such a map must have been enormous, especially when we remember that since the instrument was without the modern refinement of an automatic action, it was necessary to place each prism in the best position for viewing the spectrum for each portion of its length by hand alone. Kirchhoff affixed a scale to his map giving the distance of the lines one from another as measured by his micrometer, and he also subjoined the approximate positions of a great number of the bright lines observed in the spectra of the terrestrial elements. Many remarkable lines are still known by Kirchhoff's numbers, among them being the ray 1474 in the green, the chief bright line given by the solar corona during a total eclipse. But there is one great drawback common to every map of the spectrum constructed by means of a prismatic spectroscope, and that is, that it only perfectly represents the spectrum as produced by an identical

set of prisms. The colors always succeed one another in the same order, but the spaces they occupy in the total length of the spectrum, as also the dispersion itself, alters with the refractive angle of the prism, with the substance of which it is made, and unless the prisms be placed in the standard position of minimum deviation of the rays, with the angle made by the incident ray with the first face of the prism. Again, since the resolving power of a spectroscope of prisms varies inversely as the third power of the wave-length of the light, and the wave-length of a violet ray is about one half of that of a red ray, it follows that with such instruments the extent given to the violet will be about eight times greater than that given to the red.

It would obviously be of great advantage if spectrosopes could be so constructed that this irrationality of dispersion, as it is termed, could be avoided, and that the same or a proportional scale could be always applied to measure the distances between the lines, whatever be the dispersion produced. This end is attained by the use of a diffraction grating to form the solar spectrum, and by employing a scale of wave-lengths. It may not be out of place, and will serve to the elucidation of what is to follow, if a few words be here devoted to the instrument and to the scale.

As is well known, light is propagated by waves set up by the molecular vibrations of the luminous source in the all-pervading ether. There are also two kinds of bending of the rays or lines of propagation of the wave-motion. The one termed refraction takes place when the wave-front passes from one medium to another, and this is made use of in the production of the spectrum by means of prisms. The other bending, termed diffraction, ensues when the main wave-front meets with an obstacle such as a screen. In this case some of the rays bend round the obstacle, forming what it has been proposed to call a *derived* wave-front, and without entering into the reasons why a spectrum should be formed, it will be sufficient to state, that if the source of light be white, a series of spectra will under ordinary circumstances be seen. Our readers may, if they be so minded, very easily verify this fact for themselves by a simple experiment. Taking a sheet of thick note-paper, cut in it a slit about two inches in length and one thirty-second part of an inch in breadth. In a second piece of paper one clean stroke of a pen-knife will cut a second slit requisite for our purpose. This latter we shall refer to as the eye-slit and to the former as the light-slit. Placing the light-slit in front of a gas flame, and looking at it

through the eye-slit, after adjusting the distance between them so as to suit one's vision, a bright line of light will be seen, and on each side of it, to right and left, a series of thin colored spectra separated by dark spaces. It will also be noted that the violet ends of these spectra are turned towards the light-slit. If the eye-slit or diffraction slit be extremely fine, the spectra are too feeble to be seen. Two very fine slits, however, equal and parallel to one another, provided they be sufficiently close, will double the brightness of the spectral bands. If now a piece of glass be taken, and by means of a dividing engine that is furnished with a very accurate micrometer screw, a number of fine parallel lines be ruled upon it extremely close together, the result will be a diffraction grating giving the colored bands of a beautiful bright color, the brilliancy depending on the number of lines ruled to the inch and the dispersion on the product formed by multiplying the order of the spectrum observed and the total number of lines ruled, and divided by the width of the diffracted beam.

The earliest gratings of this sort were thus ruled by Nobert and Rutherford. Professor Rowland of Baltimore has by means of a magnificently even screw produced wonderfully fine gratings, some with 28,876 lines to the inch. They are ruled not on glass, but on polished speculum metal, and the spectra are produced by reflection from the minutely thin bright spaces between the lines, which correspond therefore to the eye-slit in our experiment with the two sheets of note-paper. The light is in this case diffracted as if the light-slit were at its virtual image behind the grating. Gratings of 14,438 lines to the inch are not uncommon, such a one of very perfect make forming part of the large spectrometer at Stonyhurst, the last instrument which the late Father Perry acquired for the Observatory. In passing it is worthy of notice that Professor Rowland has accomplished the feat of ruling as many as 43,000 lines to the inch. In all the spectra produced by the gratings, any two lines are distant from one another by an interval, which is always proportional to the difference of the wave-lengths of the light corresponding to the lines. On this account the same standard scale of wave-lengths can always be used with maps constructed by the aid of these instruments. Practically, then, all that is required is, to determine the absolute wave-length of any one line, and the absolute wave-lengths of all the others can be obtained relatively to this line. Of the extreme red there are 36,920 wave-lengths in one inch, and 64,630 of the extreme violet, so that we cannot

quite see an octave. But for the sake of uniformity the wave-lengths of light are expressed in terms of a unit called a tenth-metre, one tenth-metre being the one ten-thousand-millionth part of a metre, and one metre being a little over thirty-nine inches. With good spectroscopes it is possible to recognize lines differing by as small an amount as the one-tenth of a tenth-metre. Taking the line D_2 as a standard, Mr. Louis Bell has by a most thorough investigation determined its wave-length as 5890.188 of our units. Basing his observations on this value of D_2 , Professor Rowland has published a list of four hundred and fifty standard wave-lengths of lines.

The celebrated Angström was the first to draw a map of the solar spectrum as produced by a grating spectroscope, and with a scale of wave-lengths, his standard being the mean of the pair of lines at Fraunhofer's E line. It appeared in 1868. A catalogue of wave-lengths was drawn up in the memoir which accompanied the plates, and this map and catalogue have been used as the standards by spectroscopists up to the present day. They are, however, surpassed in accuracy by the recent determination of wave-lengths at Baltimore and at Potsdam, so that they will without doubt be supplanted in the near future.

With these preliminary remarks on mapping the solar spectrum in general, we may now turn to the review of some recent work in this direction. The name of the late M. Thollon is one that occupies a prominent place among those of modern solar observers. About ten years ago this eminent astronomer commenced a map of the solar spectrum, which as we are told in the Introduction to the accompanying catalogue which gives the places and intensities of the lines, was intended by its author to be nothing less than a standard work, furnishing to the spectroscopist similar data for his researches, as are provided for the celestial cartographer by such charts as those of Argelander. Unfortunately for the cause of science the hand of death removed him before the completion of his self imposed task. Yet not before he had by the labors of seven years succeeded in mapping the lines, from A in the extreme red through the orange to *b* in the green. The reproduction of the charts by steel engraving by M. Legros, aided by M. Perrotin, the Director of the Nice Observatory, which it would be difficult to extol too highly, has occupied another three years. They finally appeared last year in the third volume of the *Annals of the Nice Observatory*. M. Bischoffsheim most generously, as is his wont, furnished the necessary funds for their engraving and publication, and copies

have been gratuitously distributed among observatories and private astronomers. M. Thollon's spectroscope consisted of prisms filled with bisulphide of carbon, giving a brilliant spectrum, the finest definition, and a great dispersion, equal in these latter respects, by the testimony of Mr. Rutherford himself, to any of the spectra given by his gratings. In order to secure an even temperature in the spectroscope, so as to avoid a change in the refractive index of the prisms, and hence want of uniformity in the scale readings, a circulation of water was maintained within the table on which the instrument rested, and also in the hollow sides of a metal case which was let down from the roof to cover it. A heliostat threw a beam of sunlight on to the slit of the collimator which passed through one side of the box, the telescope being similarly fitted into another side.

The atlas he drew is divided into 33 maps, each about a foot in length, and shows about 3,200 lines. Each map is divided into four strips, so as practically to quadruple the atlas. These show the solar spectrum under four different conditions; first, as obtained from the sun at an altitude of 10° , the air being fairly dry, secondly, with the sun 30° above the horizon, the aqueous vapor being in abundance, thirdly, with the sun at the same altitude, but the air being very dry, and lastly with our atmosphere hypothetically removed, and therefore only lines of purely solar origin remaining. The lines in each strip are drawn most accurately, with their proper shading and thickness. Any one who has ever even casually studied the solar spectrum, can form some estimation of the painstaking and continuous toil necessary for such a task. Those only who have tried to delineate a small portion of the spectrum can fully realize what a demand the drawing of such maps makes on the care and patience of the observer. It is only necessary to compare the picture with the original to see how perfectly M. Thollon has succeeded. The great utility of the map consists in its bringing together in parallel strips the solar spectrum as seen under various atmospheric conditions. It is thus possible by a comparison of the intensity of the same lines in the different strips to eliminate those caused by our atmosphere. For a true solar line will remain always of the same intensity, the atmospheric line meanwhile varying with the hygrometric state of the air. It would appear that of the 3,200 lines mapped by Thollon, 2,090 are purely solar, 866 are telluric or air lines, and 246 are traceable to the combined action of both the terrestrial and solar atmospheres. But as a standard the map has already been superseded by recent photographic

studies, for it labors under the defect already noticed as inherent in all maps constructed by means of prismatic spectrosopes, of not furnishing a normal scale. It is none the less an admirable piece of work, and beyond all praise. Indeed, it seems difficult to imagine that more perfect or more delicate drawings could be produced, and it marks the highest level yet reached by means of the pencil. It only remains to add that M. Trépied, the colleague of M. Thollon, has undertaken to complete the remaining two-thirds of the work.

As early as 1843, J. W. Draper, applying the but recent invention of Daguerre, obtained a plate by this process of nearly the whole length of the spectrum. In 1874 again, Rutherford, working with a prismatic spectrope, was able to publish a fine photograph of the blue and violet ends of the spectrum. Nor must we omit to mention the standard map of the ultra-violet unseen region of the spectrum, the fruit of the labors of Cornu. But the recent progress in photographic science, and more especially the invention of the dry-plate process, which is both cleanly and easy to manipulate, while capable of almost any extent of sensitiveness, has placed in the hands of the astronomical physicist a most potent instrument of research when brought to the aid of either telescope or spectrope. The photograph of the nebula in Orion obtained on a dry plate in 1880 by H. Draper was the first of a series of triumphs in this kind of work, and already celestial photography has advanced our knowledge of the heavens to an extent which could not have been dreamed of by the astronomers of the middle of the century. Nor has the solar spectroscopist been backward in availing himself of this powerful aid to unravelling the secrets of the solar spectrum. The same year that Draper photographed the nebula in Orion, Professor Rowland, of the Johns Hopkins University, invented a plan, by which it became possible to vastly increase the accuracy attainable in the cutting of micrometer screws. Possessing a perfect screw, he commenced to rule correspondingly perfect gratings, without any periodic error in the ruling above the hundred-thousandth part of an inch. The spectra produced by Rowland's gratings are therefore particularly free from the obnoxious false images of the principal lines of the solar spectrum termed "ghosts." These are caused by a periodic inequality in the spaces contained between the parallel scratches of the diamond point on the speculum metal. For instance, let us suppose that one turn of the micrometer head be equivalent to the ruling of 1,000 lines, should any unequal spaces occur in the

course of a revolution, they would occur relatively in the same places in every revolution. These periodic unequal spaces gave their own fainter spectra, which naturally were more evident in the principal lines, and so caused the "ghosts" already mentioned. Good gratings, as now ruled, such as the one possessed by the Stonyhurst Observatory, are quite free from this fault. This advance in the perfecting of the ruling of gratings Rowland followed up the next year by conceiving the brilliant idea of ruling the gratings on a spherical surface of speculum metal, instead of on flats as had hitherto been done. By this means it is possible to dispense with all the adjuncts of an ordinary spectroscope except the slit, the grating, and the eye-piece, in the place of which last a camera may be substituted. Such a spectroscope is simplicity itself, there being no need of a collimating lens to render the divergent pencil of light from the slit parallel before reaching the grating, nor yet of any telescope to focus the rays.

With a grating perfectly ruled on a spherical surface 6 inches in diameter and $21\frac{1}{2}$ feet radius, the Professor undertook to photograph the solar spectrum. His map was published in 1886, followed in 1889 by a second more perfect edition. This second edition extends from wave-length 3,000 far down in the violet, to wave-length 6,950 beyond B in the red. Kirchhoff's coronal line 1,474, which was once supposed to be coincident with an iron line, was clearly separated into two lines, as was also b_3 , which used to be attributed to both magnesium and iron. The E line was also first resolved.

But the most successful photographer of the solar spectrum who has yet appeared is undoubtedly Mr. George Higgs, of Liverpool. It has been our privilege to examine this gentleman's apparatus, processes, and original plates under his own guidance, and we propose to briefly describe some few of his methods and results. And first of all we must call attention to the fact that, except for the concave grating and the screw of the engine for ruling scales, every piece of apparatus used by this astronomer has been made by himself, and is remarkable alike for simplicity and the ingenuity displayed. Even the Rhumkorff coil for use in producing the spectra of terrestrial substances for comparison with the solar lines, is of his own constructing. This instrument, which was exhibited before the British Association at its Manchester meeting, is of such perfect insulation, and such complete economy of insulation and just proportion of parts, that with one quart bichromate of potash cell it gives a spark of

ten and a quarter inches. And yet only fifteen miles of wire have been wound upon it.*

Mr. Higgs first began work on the solar spectrum with a prismatic spectroscope, with which he produced a very beautiful photographic map. He then acquired a grating, one of Rowland's spherical instruments ruled with 14,438 lines to the inch, having a diameter of four inches and a radius of curvature of ten feet two inches. Now the purity of a spectrum is inversely proportional to the width of the slit. From this it is evident that if the jaws of the slit, the light-slit of our simple experiment, are perfectly sharply cut and exactly parallel, it becomes possible to make it excessively narrow, provided always that the illumination be sufficient. It would appear that a great deal of Mr. Higgs' success is attributable to the fine steel-jawed slit which he has made for his spectroscope. The grating is mounted at one end of the diameter of a circular table, equal to the radius of curvature of the grating, and the eye-piece or camera is placed at the other extremity of this diameter. The slit also slides along the circumference of the table, and is placed in different positions with regard to the grating and camera, according to the order of the spectrum which is to be photographed. The circumference is divided into parts by means of a scale encircling it, which is also supplied with moveable verniers. These scales again are Mr. Higgs' handiwork, and the perfection of adjustment attainable by their aid in his instrument is another source of its fine performance. The light is conducted to the slit by a heliostat, this, too, made, with its silvered mirror, by the observer. In photographing the solar spectrum the actinic action at the two ends of the plate varies immensely, being in some cases as much as fifty times greater at one end than at the other. The plate must therefore be exposed at different portions of its length for different times, otherwise while one end of the plate would be over-exposed, the other would have failed to have registered any line at all. This difficulty is overcome by Mr. Higgs by means of a set of shutters placed inside the camera, and worked by clock-work, and so arranged that the proper relative exposure is secured for every portion of the sensitive film.

It might perhaps be imagined by such as are unacquainted with

* At the time of our visit the instrument had not been employed for a considerable period, and the battery had so deteriorated that it would ordinarily have been rejected as unfit for use. Yet it gave a spark which leapt across the terminals at a distance of seven inches, and when the zinc and carbon were lifted out of the solution and put into clean water, it gave a continuous spark of one inch and a quarter. Electricians will appreciate the accuracy of workmanship required to attain such a result!

the action of light upon photographic films, that after all this care in adjustment nothing further was required but the exposure of the plate for the proper time in order to obtain a picture. But not so; for first, the actinic action of light is chiefly confined to the blue and violet regions of the spectrum, and secondly, although in spectra produced by means of gratings the first spectra on each side of the white image of the slit, called the spectra of the first order, are separated from those of the second order, yet the second, third, and higher orders overlap. Hence, should it be required, for instance, to use the greater dispersion of the red of the second order, it becomes necessary to block out the violet of the third order. The suppression of the obnoxious rays is effected by the absorbing action on light of suitable solutions, which are contained in glass cells and placed before the slit. But the problem of rendering the plates themselves sensitive to the lower wave-lengths of light is by no means an easy one. It has engaged the attention of several eminent photographers. One method devised by Captain Abney was the preparation of the bromide of silver plates, with the salt in a different molecular condition from that in which it is ordinarily found, so that it looked blue by transmitted light. By this means he was enabled to directly photograph the dark heat rays of the solar spectrum. Others, again, as Vogel and McClean, have proceeded in a different manner, and have sensitized the plates for radiations above the blue by staining them with various dyes. Higgs, too, has been most successful in this field, and has but recently communicated to the Royal Society a paper in which he announces the discovery, that plates stained with the bisulphite compounds of alizarin-blue or of coerulin, while sensitive to the red and ultra-red rays between the wave-lengths 6,200 and 8,000, do not, like cyanin plates, lose the power of retaining the impression of the rays at the opposite end of the spectrum. With such plates he has been enabled to extend the range of his photographs to Z in the ultra-red, while his photograph of A exhibited at a British Association Meeting at Leeds, and to the Royal Astronomical Society, shows the lines of this beautiful group as they have never been seen before.

When the negative has been secured, it is enlarged four times, evenness of background and sharpness of detail being obtained by the use of a cylindrical lens, and by other ingenious arrangements which need not be described here. The prints which are the finished results, have the fineness of steel engravings. Moreover, by a very clever device Mr. Higgs photographs a scale of

wave-lengths on his map, a boon which will be appreciated by every working spectroscopist. More than this, by photographing the unknown coincidently with the known regions on the same plate, and placing the scale between them, provided only the two slips are of different orders, a very simple relation enables the wave-lengths of the unknown lines to be determined. He has even an original method for securing a certain knowledge that the temperature of the scale has not altered during the time of its being ruled by the dividing-engine. Finally, it is his intention to publish in the near future a map of the whole spectrum from wave-length 2,990 in the ultra-violet to wave-length 8,500 in the ultra-red, with special studies on interesting regions.

When we look at some of the best maps of the solar spectrum, so crowded with lines that it would be impossible in parts to place a needle-point on the pictures without alighting on a line, the questions naturally arise as to what substances these innumerable lines belong to, and what progress has been made in identifying the relations between the solar spectrum and the laboratory spectra of the elements. We intend briefly to record some few of the more recent investigations. A most necessary preliminary step in solar spectroscopy is the discrimination of the lines of purely solar origin from those which are due to the absorbent action of the Earth's atmosphere. We have already called attention to the value of Thollon's map for this research, as by a comparison of the intensity and thickness of the lines in the four strips, it is possible to detect those which vary concomitantly with the altitude of the Sun above the horizon, and with the hygrometric condition of the atmosphere. One of the finest groups of lines in the solar spectrum occurs in the red at Fraunhofer's B. Some of Mr. Higgs' photographs bring out the rythmical arrangement of the lines in this group most beautifully. But it had by Egoroff and Janssen been identified as most probably not due to the Sun, but to the dry oxygen contained in our atmosphere. The latter astronomer, who bears a distinguished name in solar physics, has lately completed a series of observations remarkable alike for their intrinsic value, as also for the circumstances under which they were carried out. Arguing that if these lines are really due to our atmosphere, their intensity should diminish in direct proportion to the height from which they are viewed, and in the impossibility of getting rid of our atmosphere altogether, this intrepid observer, whom nothing daunts—for had he not already escaped the vigilance of the Prussians who were besieging Paris, and passed out in a balloon to observe the eclipse of 1870

—would now have himself carried to the tops of the highest mountains to note the effect on the suspected oxygen lines. In accordance with his plan he ascended to the Grands Mulets in 1888, and last year was borne in a litter by a small army of guides to the very summit of Mount Blanc. The result was a complete verification of his earlier observations, so that we may conclude that most probably oxygen, at least in the state in which we know it here, does not exist in the solar envelopes. He has likewise experimented from his Observatory at Meudon on an oxygenless light set on the highest point of Eiffel Tower, the atmospheric strata traversed by the rays being nearly equivalent to the height of the atmosphere supposed homogeneous. The oxygen lines in this case appeared exactly as they are seen in the solar spectrum, thus adding another link to the chain of proof of their terrestrial origin.

With regard to other lines due to the Earth's atmosphere, Dr. L. Becker, of the Edinburgh Royal Observatory, has quite recently published the results of long and laborious observations of the solar spectrum at low and medium altitudes. The spectrum drawn extends from wave-length 6,024 to F in the blue-green. In this range of the spectrum, 3,637 lines are identified as due to the sun, and 928 as air lines. For the purposes of such an investigation, the photographs of Mr. Higgs will, when published, be extremely valuable. For they have been taken with the sun at various altitudes, and under different conditions of saturation of the atmosphere. One plate in particular showing D and the lines constituting the rain-bands, when the Sun was only just its own diameter above the horizon, is a superb production. Again, in several cases the enlarged photographs show metallic lines and air lines so close together that no spectroscope except those of the very greatest resolving power could separate them. Such results may not improbably have an effect upon theories which are founded upon the behavior of lines in the spectra of Sun-spots. In passing too we may remark that of some other lines, which it is considered a feat to have split, the photographs of this observer divide not only the coronal line, but also the E line and one twice as close at 5264.4. The head of the B group too is seen to be composed of three lines, while from twenty-five to thirty lines are registered between the D's and no less than one hundred and fifty between H and K.

Nor in the meantime have Professor Rowland and his assistants been idle, but they have brought the powerful apparatus of the Johns Hopkins University to bear upon the photographing of

the lines in the metallic spectra coincidently with the solar spectrum. Kirchhoff's list of metals in the Sun, deduced from his observations taken about twenty-five years ago, consisted of sodium, iron, calcium, magnesium, nickel, barium, copper, and zinc. To these Angström and Thalen added chromium, cobalt, hydrogen, manganese, and titanium; while Lockyer, later still, by an ingenious method of laboratory work, brought the total up to twenty-three. He detected aluminum, strontium, lead, cadmium, cerium, uranium, potassium, vanadium, palladium and molybdenum. Of these coincidences with the dark solar lines, about six hundred were attributed to iron alone. And now the latest list, quite recently issued by Professor Rowland from photographs taken between the ultra-violet and the D lines, gives the total number of terrestrial elements certainly present in the Sun as thirty-six, while eight more are doubtful. In this latter category is uranium, formerly admitted as present by Lockyer. Rowland's most important addition is carbon, the others being silicon, scandium, yttrium, zirconium, lanthanum, niobium, neodymium, glucinum, germanium, rhodium, silver, tin, and erbium. But the solar photosphere contains no gold, nor antimony, arsenic, bismuth, boron, nitrogen, caesium, indium, mercury, phosphorus, rubidium, selenium, sulphur, thallium, nor praseodymium; while iridium, osmium, platinum, ruthenium, tantalum, thorium, and tungsten, are, together with uranium referred to before, recorded as doubtful. These lists have been arranged both according to the intensity of the metallic lines in the Sun, and according to their number. In the latter series iron occupies the first place with two thousand and nine lines, nickel comes next, and two hundred coincidences are due to carbon.

In concluding this necessarily brief summary of some recent spectroscopic studies in but one branch of modern astronomical physics, we may be allowed to again direct attention to the fact of the importance of the aid to research which the observer has acquired in the spectroscope and the photographic camera. Already we know that the materials of which our Sun is constituted are the same as we find here upon Earth. But our Sun is but one out of millions which glitter as stars in the heavenly firmament. It is a truly wonderful thing that a piece of glass cut into the form of a prism, and a plate of glass covered with a gelatine film, should be so arranged in position behind another piece of glass fashioned into the shape of a lens that these immeasurably distant stars should be compelled to tell us of what they are made. But wonderful as it seems, the mind of man has

been able to effect so much, and has thus obtained a deeper insight into the marvelous harmony and unity which reigns in the starry skies. With this insight ought to come deeper reverence, and our spirit should be that of the pious Kepler, who was wont to cry out as he contemplated the heavens: "O God, I think Thy thoughts after Thee."

ST. BEUNO'S COLLEGE, St. Asaph, N. Wales.

SOLAR PHOTOGRAPHY AT THE KENWOOD ASTRO-PHYSICAL OBSERVATORY.

GEORGE E. HALE.

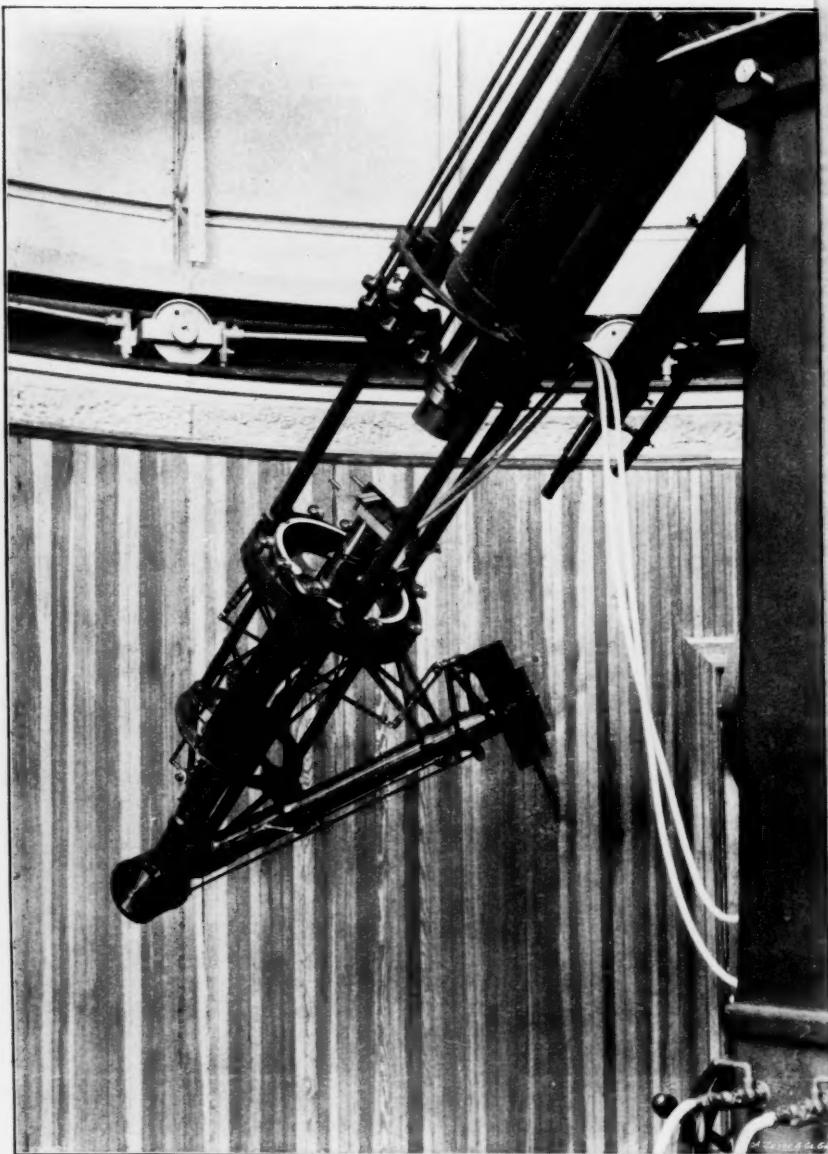
Immediately after the completion of our 12-inch equatorial refractor in March, 1891, an investigation was undertaken at the Kenwood Observatory which had for its object the application of photographic methods to the registration of all classes of solar phenomena. Up to that time, in spite of various attempts at photographing the prominences, the only phenomena at the Sun's surface which had been photographed with any degree of success were the spots, and the faculae *when very near the limb*. As they are carried toward the center of the disc by the Sun's rotation, the faculae no sooner leave a narrow area near the limb than they are lost to view on the brilliant background of the photosphere, and ordinary methods of photography serve no better than the eye itself in following the course of these objects. For lack of photographic means the numerous prominences rising from the Sun's limb must needs be drawn one by one—a laborious process at best, and one consuming far too much of valuable time. Moreover, the spectra of faculae, spots and prominences in the invisible region of the ultra-violet were then uninvestigated, and there was the possibility that other phenomena, as yet unknown, might be brought to our knowledge by the peculiar powers of the sensitive plate. These considerations had first occupied my attention in 1889, and I had then devised methods to overcome some of the many difficulties in view, but though preliminary experiments had been carried on at the Harvard College Observatory in the winter of 1889-90, they had been quite without success, on account of the unsuitability of the apparatus employed. The field was, therefore, a practically untried one when we entered it at the Kenwood Observatory just a year ago.

I have already described the new lines discovered in the spectra

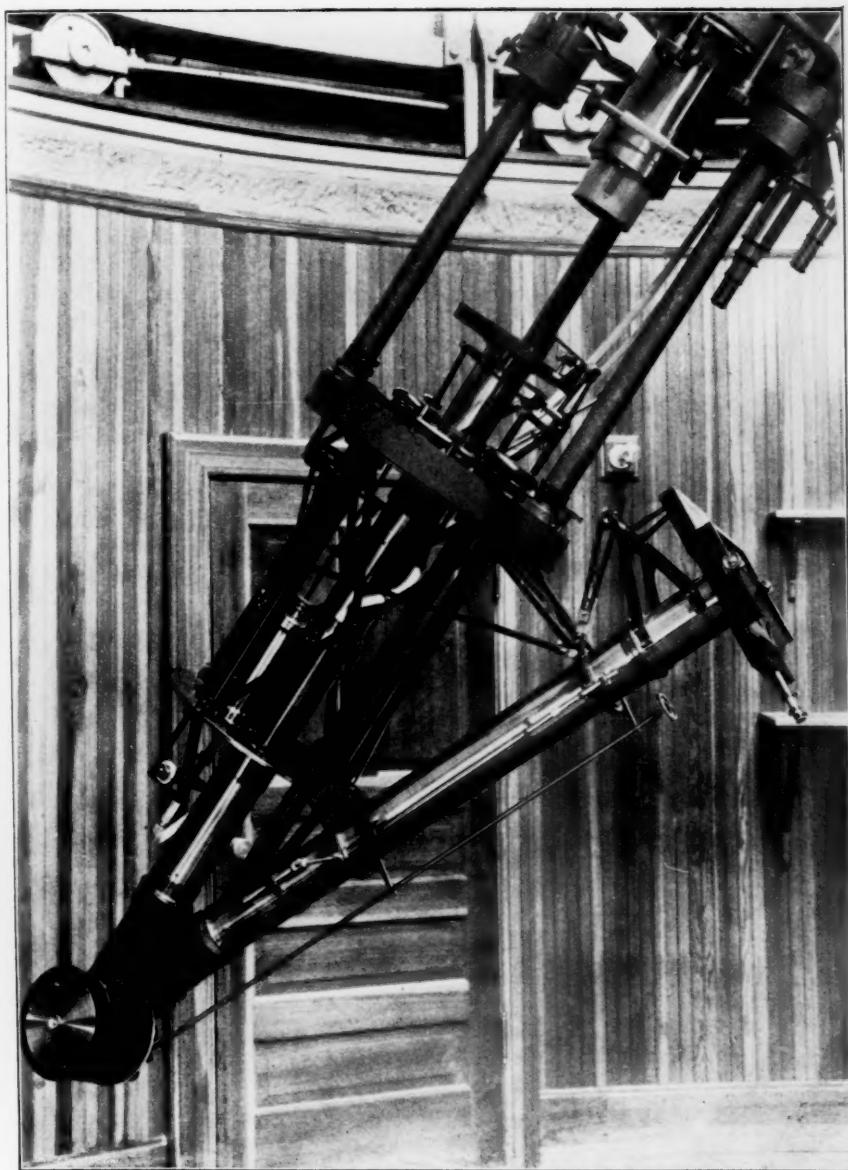
of prominences, spots and faculæ, and the photographs obtained of single prominences with the H and K lines and an open slit. In the present paper I wish to explain the method by which photographs are now made of all the prominences visible around the entire circumference of the Sun with a single exposure, and by which faculæ are clearly shown even in the brightest portions of the Sun's disc.

In the *SIDEREAL MESSENGER*, June, 1891, I described the difficulties experienced in photographing prominences by my first method. The apparatus as then used consisted of a cylinder in a closed box at the eye-end of the observing telescope of a large diffraction spectroscope. The axis of the cylinder was parallel to the lines in the spectrum, and the cylinder could be rotated at a uniform rate by a small clepsydra, attached to the instrument. Thus a strip of flexible celluloid photographic film on the circumference of the cylinder was slowly moved in the plane of dispersion behind a narrow slit at the focus of the observing telescope. The grating was rotated by a tangent screw until the K line in the fourth order spectrum passed through the narrow slit, and fell upon the sensitive film. By changing the rate of the driving clock of the telescope the Sun's image was made to drift slowly across the (first) slit of the spectroscope, while the film rotated at the proper speed. As K is always bright in prominences it follows that the successive images of this line as a prominence moved across the slit would build up the required form upon the photographic film. A number of fairly good photographs of prominences were obtained in this way, but so many defects were discovered in the apparatus, and the difficulty of securing the proper ratio between the motion of the film and the rate of the telescope clock was so great, that it was decided to construct an entirely new instrument, on the principle of my second method as devised in 1889.

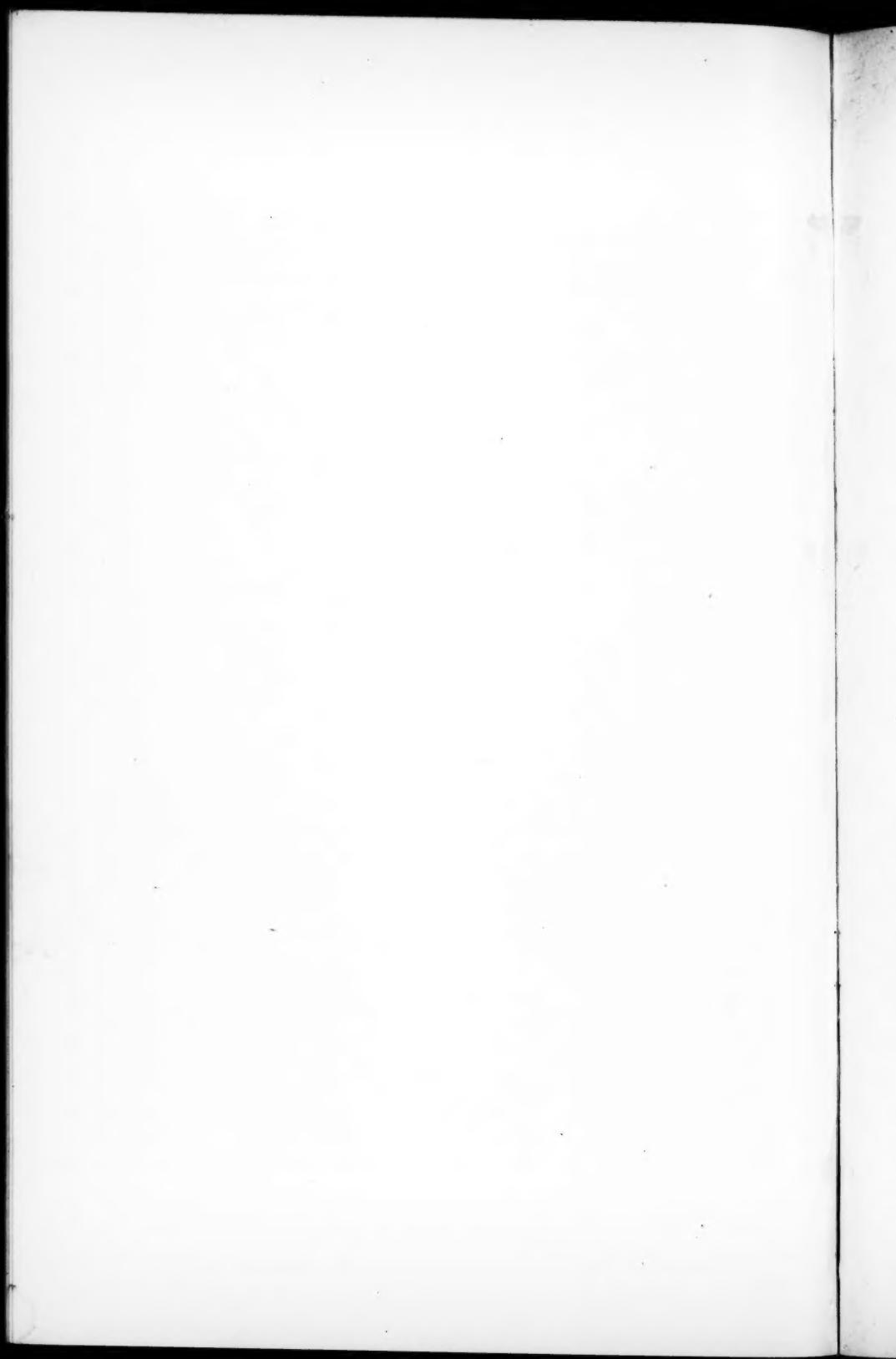
This apparatus, which I have called a "spectroheliograph," is shown in the accompanying Plates attached to the eye-end of the 12-inch equatorial. Its essential parts are two movable slits, one at the focus of the collimator of a large grating spectroscope, and the other just within the focus of the observing telescope. The slits are about $3\frac{1}{4}$ inches in length, and adjustable in width. They are attached to carriages mounted on steel balls, so that they may be moved with perfect freedom across the axes of the tubes, in the plane of dispersion. A photographic plate-holder is supported just beyond the second slit, and, after drawing the slide, the plate-holder can be pushed forward by means



THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO.



THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO.



of a cam until the surface of the plate almost touches the jaws of the slit. A small 90° total reflection prism is attached to the slit carriage on the side toward the grating, and by a suitable combination of lenses a small portion of the spectrum can be viewed without disturbing the plate-holder.

The motive power is supplied by a specially designed clepsydra, which is mounted within the braced frame of the spectroscope. It consists of a brass cylinder of 3 inches bore and 6 inches stroke, supplied with two inlet and two outlet valves, and a very accurately made micrometer gate-valve. The piston has a cup-shaped leather packing, and the phosphor-bronze piston-rod passes through a stuffing-box in the upper head. At the end of the rod a system of bell-crank levers is attached, and these convey the motion to the slit at the focus of the observing telescope. An extension of the piston-rod passes through a guide in the upper frame of the spectroscope, and connects with the first slit by another lever system. It will be seen that when the piston is set in motion, the two slits will move simultaneously, and in opposite directions.

The city water supply could not be used to run the clepsydra for two reasons. In the first place the pressure must be constant or nearly so, while the city pressure undergoes marked variations. Again, the water would freeze in cold winter weather. I therefore had a hydraulic accumulator constructed, and placed in the cellar of the Observatory, with galvanized iron pipes leading up to the observing room, and terminating in stop-cocks on the iron pier of the equatorial. Union joints attached to flexible rubber tubing put the accumulator in connection with the clepsydra, and do not hinder in the least the free movement of the telescope. The liquid used is a mixture of water with about 30 per cent of alcohol, and this proved quite satisfactory even in cold weather. The accumulator consists simply of a large vertical cylinder, with a yoke suspending from the upper end of the piston-rod about half a ton of iron weights. The descending piston forces the liquid through a supply pipe at the bottom of the cylinder, and the returning liquid enters the top of the cylinder. When completely run down the piston is pulled up by means of a differential block, the liquid passing from above the piston to the bottom of the cylinder by an outside pipe, open into the upper part of the cylinder, but with a check-valve at the bottom. For summer work I intend to have the city water connected with the bottom of the cylinder, and the weighted piston will then make up for any variations in pressure. The city pressure will probably be sufficient to

free us from the labor of using the differential block during the warmer months of the year.

It will be seen in the Plates that the supply pipe enters the clepsydra at the upper end, while the waste passes out through a pipe in the lower head. The brass pipe to which the supply tube is connected runs the whole length of the cylinder, and the liquid can thus be admitted on either the upper or lower side of the piston by opening the proper valve. In the photographs both valves are closed. Supposing the cylinder to be filled on both sides of the piston, we can run the piston down by opening the upper inlet valve and the outlet valve just above the micrometer gate-valve in the pipe leading from the lower head. The speed of the piston's descent, and hence the speed of the two slits, can be regulated with the utmost nicety by the gate-valve, the micrometer head of which is divided into 100 parts. The gate-valve has a pair of phosphor-bronze jaws in the form of an adjustable slit, and a wide range of motion is thus secured. Provided the pressure remains constant, a given speed can be obtained at any time by setting the micrometer head at the proper reading. When the piston has reached the end of its course the upper inlet and lower outlet valves are closed, and the lower inlet and an upper outlet valve, opening into an outlet pipe on the farther side of the cylinder, are opened. The piston then returns to the upper end, moving the slits to their opposite extreme positions. The full run of the slits is about $3\frac{1}{4}$ inches, corresponding with the aperture of the telescopes to which they are attached.

Although the spectroscope has been previously described, it may be as well to recall the general features of its construction, which has recently been modified. New objectives, corrected for the K line, have been supplied for the collimator and observing telescopes. In aperture ($3\frac{1}{4}$ inches) and focal length (42 $\frac{1}{2}$ inches) they are identical with the visual objectives formerly used, and they can be readily replaced by these for work in the visual region. A photographic objective of 85 inches focus is also available for photographing the spectrum, and for its accomodation the short section of tube carrying the second moving slit at the end of the observing telescope can be unscrewed, and a tube about 42 inches long, with a plate-holder at one extremity, screwed on in its place. The same plate-holder can also be used with the short focus objective, and the section of tube carrying the holder screws on for this purpose in place of the long tube. The observing telescope is focussed from the eye-end by a screw moving the objective along the axis of the tube. The Sun's

image is brought to focus on the first slit by a motion of the entire collimator through collars in the supporting frame of the spectrograph. The Rowland grating has 14,438 lines to the inch, and is covered by a brass box. It can be rotated about an axis parallel to the lines of the ruling by means of a tangent screw in connection with a rod leading to the eye-end of the observing telescope. It is also supplied with the other usual adjustments. The whole spectroheliograph can be rotated about the axis of the collimator by means of a rack and either one of two pinions in the supporting ring, and the direction of the slit is shown by the moving index of a large fixed position circle. The moving slit on the collimator can be easily replaced by the excellent fixed slit formerly used. This has recently been much improved, and fitted with new pairs of straight and curved jaws, as well as a prism behind the slit, for use in accurately setting the instrument on a small object.

Although made as light as is consistent with thorough rigidity, the spectroheliograph weighs about 250 pounds. But as the mounting of the equatorial was constructed with this fact in view, the instrument is carried with great ease and smoothness.

I cannot speak too highly of the care and accuracy with which Mr. J. A. Brashear has constructed the entire apparatus. To his skillful foreman, Mr. George Klages, much credit is due for the excellent manner in which he has worked out many features of the design. I am also indebted to the experience in hydraulic engineering of Mr. T. E. Brown, for important suggestions as to the improved form of clepsydra.

Though the spectroheliograph is apparently somewhat complicated, its manipulation is extremely simple. The method requires that the first slit move gradually across the image of the Sun at the focus of the equatorial, while the second slit moves at such a rate that the K line constantly falls upon the fixed photographic plate. Images of any regions on the Sun in which the K line is reversed must then be obtained upon the sensitive surface, requiring only the ordinary method of development to permanently register them.

To make the use of the instrument clear I will describe the operation of photographing the prominences around the circumference of the solar disc. The center of the Sun's image formed by the equatorial (this image is about 2 inches in diameter) is made to coincide with the axis of the collimator, and maintained in this position by the driving-clock. The whole spectroheliograph is then rotated until the slit is parallel to the Sun's axis.

The dust lines, which are unavoidable in the spectrum when a narrow slit is used, are thus made to indicate the direction of the solar equator in the photograph. After having moved the collimator tube until the scale reading indicates that the first slit is at the focus of the equatorial for K, and the objective of the observing telescope until it is in focus for the same line, the slits are brought to the center of the field by opening the proper valves in the clepsydra. While observing the spectrum through the second slit with a positive eye-piece (the plate-holder being supposed removed) the grating is rotated until the region of the green in the third order spectrum which overlies the K line in the fourth order is seen in the middle of the slit. (This adjustment can be made once for all, for by next noting what line in the green falls on the cross-hair while observing the spectrum with the small diagonal prism described above, it is only necessary for subsequent exposures to set this line on the cross-hair, when K must pass through the second slit. For the prism moves with the slit, and the distance between them is constant in all positions of the latter. This allows all future settings on the K line to be made when the photographic plate is in place.) The direct light from the greater portion of the Sun's disc is then excluded by a circular diaphragm slightly smaller than the solar image, supported just in front of the first slit; the piston is run to the upper end of the clepsydra; the micrometer head of the gate-valve set at the proper reading; the plate-holder placed in position, the slide drawn, and the holder pushed forward into the focal plane by turning the cam; the proper valves of the clepsydra are opened, and as the slit sweeps across the middle of the field the moment of the exposure is recorded in the note-book. On developing the plate all the prominences around the entire circumference of the Sun are found in their proper forms and positions.*

Anyone familiar with the spectroheliograph can easily make all the adjustments and secure a photograph of the prominences in less than two minutes time. After the first photograph as many as are desired may be taken at intervals of about one minute. To say nothing of the gain in accuracy, the great saving of time

* Subject, of course, to the distortion which the grating produces in the plane of dispersion. Using the K line in the fourth order, the Sun's disc with the present instrument is an ellipse, with its minor axis in the plane of dispersion. The distortion does no harm in plates intended for measurement, as it may readily be allowed for. I have devised several methods, mechanical and optical, by which the circular form of the image may be restored. One of the simplest and most satisfactory of these is to use no driving-clock in photographing, but allow the Sun to move across the field during the exposure, in the same direction with the first slit. The speed of the slit then determines the form, and sharply defined circular images have thus been obtained.

is apparent when it is remembered that so skillful an observer as the late Father Secchi estimated that one hour is required to properly record all prominences around the circumference by the ordinary method. Our record may now be unbroken even on days when clouds prevent an hour's observation. Moreover, on clear days several photographs may be obtained in the morning and afternoon. As many prominences last but a few hours or even minutes, this is important. At present I do not know that more than one complete record of all prominences is made in a single day at any observatory, even under the clear skies of Italy.

But the great advantage of photography is most apparent during the sudden and short-lived eruptions, with which all solar observers are familiar. At such times I leave the visual observations of the phenomenon entirely to my assistant—who employs the 4-inch equatorial and small grating spectroscope—and spend my time making photograph after photograph, thus securing a most complete and accurate record of the development and dissolution of the prominence.

Let us now consider another class of solar phenomena, for the registration of which the spectroheliograph has proved to be of great value. I refer to the faculae.

In his catalogue of the bright lines in the spectrum of the chromosphere, published in 1872,* Professor Young remarks as follows in regard to the H and K lines: "They were also found to be regularly reversed upon the body of the Sun itself, in the *penumbra and immediate neighborhood of every important spot*." The observations referred to were made under the exceptional atmospheric advantages enjoyed at the summit of Mount Sherman, but even with the less favorable conditions common at the sea-level, the same observer has repeatedly made out similar reversals in many spots. I do not know that these observations were confirmed elsewhere until the photographs made at this Observatory in April, 1891, brought out the same thing with great clearness. A few months later Professor Young secured at Princeton some photographs of the reversals, but my own attention has, until recently, been so fully occupied with work on the prominences that I have had but little opportunity to go on with my proposed photographic study of spot spectra. Late in December, however, I secured some photographs of the spectrum of a spot in which the lines were so sharply defined that they were given a very careful examination. Not only were the

* *American Journal of Science*, Nov. 1872.

bright lines at H and K more prominent in the penumbra than in the umbra of the spot, but their extent in the surrounding region was so great as to arouse the suspicion that similar reversals might be found on the disc, at points remote from spot regions. To test this idea, a series of six photographs of the spectrum was taken, the slit in each case being placed parallel to the position it had occupied during the exposure just preceding, and about 3' distant from it. My expectations were not only realized by these photographs, but greatly surpassed. In each of the six positions of a slit not more than 0.002 inch wide the K line was reversed in from three to ten places. H was, without doubt, similarly affected in all of these points, but in some cases it was too faint to be certainly seen. Most, if not all, of these reversals were double, *i. e.*, a dark line ran through the center of the bright line, as is frequently observed in the spectrum of the electric arc. I have since suspected in several cases a strengthening of the broad dark absorption bands of the solar spectrum for a short distance on both sides of the bright reversals.

Having thus found the surface of the Sun to be dotted over with regions in which the H and K lines are bright, I at once concluded that the *forms* of the reversed regions might be photographed with the spectroheliograph, in exactly the same way that prominences around the circumference are obtained. The first attempt to do this was made on January 12, when the adjustments of the instrument were incomplete, and connection had not been established between the accumulator and the clepsydra. In lack of more suitable motive power, the slits were moved by hand, and even in this way bright forms near a spot group were shown on the photographs, though they could not be seen with the helioscope. The completion of the apparatus a few days later enabled me to secure very good photographs of the bright regions, and on comparing them with drawings and photographs, taken in the ordinary way, of faculae near the limb, it was found that the forms were identical.

The great advantage of the new method of photographing faculae is at once evident. Taking little account of the difference in brilliancy between the limb and the center of the Sun's disc, it allows us to photograph faculae wherever they may be in the visible hemisphere. The investigation of these objects has heretofore been so restricted, that it may be truly said that we are now enabled, for the first time, to study them with any degree of completeness.

One of the most interesting and important of all the solar

questions with which we have to deal is the relation existing between spots, prominences and faculae. In the long discussion in the *Comptes rendus*, in which M. Faye vigorously defended his theory of Sun-spots against all comers, he stoutly maintained that prominences and faculae result from spots and pores, while his opponents, MM. Secchi and Tacchini, were as fully convinced that we must look to faculae and prominences for the true explanation of spots. Both parties agreed, however, that faculae are often the sources from which prominences spring, and this conclusion is sustained by the first results obtained photographically. In the large number of plates already secured, there are many instances in which faculae at the limb are shown to project a short distance above the boundary of the photosphere. Indeed, though the prominences usually require a slower motion of the slit, and consequently a longer exposure, than that which is most suitable for faculae, in several cases they have been bright enough to appear on plates where only faculae were expected. As both have the same bright lines in their spectra, and both project above the level of the photosphere, a facula might almost be defined as a small prominence possessing a continuous spectrum in addition to its bright lines.

But while it is not difficult to separate the two classes of phenomena at the Sun's limb, the distinction becomes much less evident, or even disappears, when they are photographed in projection on the disc. Given a *sufficiently bright prominence* at any point on the visible hemisphere, and the spectroheliograph cannot fail to show its form as well as those of the faculae. A possible instance of this kind was given in my paper on the great spot-group of February, 1892 (ASTRONOMY AND ASTRO-PHYSICS, April, 1892). The forms of the bright regions in the midst of the spot-group as observed through the C line, and photographed through K, were found to agree. It has usually been assumed that the reversed regions, which have occasionally been seen in this way near spots, were prominences. I see no reason why they may not be equally well regarded as faculae, for, like H and K, C is bright in both. As faculae do not, as a rule, undergo rapid variations in form, a criterion may perhaps be found in this fact, for bright prominences are usually active ones. I have already mentioned that the bright H and K lines on the disc have as yet given no indication of motion in the line of sight, and this may point to their origin in faculae, rather than in prominences. It seems probable that ordinary prominences cannot be seen

when projected on the disc, as their temperature may be lower than that of the brilliant background.

At the meeting of the Chicago Academy of Sciences on April 12, 1892, I presented a preliminary note on the forms of the faculae, as they are shown in the daily series of photographs obtained with the spectroheliograph. My attention was first directed to this subject by a remarkable facula photographed in the central region of the great spot group, as it appeared at the Sun's eastern limb on February 4, 1892. In shape this facula was similar to the letter S, one extremity of which terminated abruptly in a small but brilliant circular expansion. On looking over other plates to see whether curved forms occur frequently in faculae, I was surprised to find several well-marked cases in every negative. This led to an examination of all the photographs of faculae in our collection. Of 137 negatives, taken between January 22 and April 12, 49 were selected. These, with one or two exceptions, were obtained on different days. The remaining 88 were either taken on the same days with some of the above, or injured by clouds, etc., and they were therefore left out of consideration. On the 49 plates, 245 cases of smooth curves in the forms of faculae were noticed on casual inspection, and in 98 cases the curved faculae terminated in bright circular heads. Spiral forms were found to be not uncommon, but the form which appears in the vast majority of cases is like that of a figure 3, the open side facing in an easterly much more frequently than in a westerly direction. Of the intimate relation of such faculae with the spots which they often enclose I shall be able to write more intelligibly in a future paper, which I hope to accompany with reproductions of some of the photographs.

Most of the following daily series of photographs are now in progress at the Kenwood Observatory, and the others will very shortly be undertaken:

a. Photographs of the Sun with a 12-inch photographic objective and enlarging lens, for shots and granulation. Diameter of image between 10 and 16 inches.

b. Photographs of the Sun with the spectroheliograph; for faculae and bright prominences on the disc. Diameter of image = 2 inches. (The general forms of spots are also shown on these plates.)

γ. Photographs of the Sun with the spectroheliograph; for chromosphere prominences around the circumference of the disc. Diameter of image = 2 inches.

δ. Photographs of the spectra of spots and faculae with the 14,438 grating; for distortion, reversal and widening of lines.

ε. Photographs of the spectra of the chromosphere and prominences with the 14,438 grating; for reversal and distortion of lines.

While it is true that photography fails as yet to record the smaller details in prominences (as it also fails in the case of spots), the merely experimental side of the investigation has been fairly passed, and we have now entered upon the practical application of photographic methods in recording all of these various classes of solar phenomena.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, April 15, 1892.

NOVA AURIGÆ.*

EDWARD C. PICKERING.

The new star in Auriga has now become very faint. It has been photographed at the Harvard College Observatory on about forty nights since December 10, 1891, and observed visually on about thirty nights since February 3, 1892. After undergoing slight fluctuations, it began to diminish in light during the latter part of February. It attained the magnitude 6.0 on the scale of the meridian photometer about March 4; 7.0, March 10; 8.0, March 13; 9.0, March 16; 10.0, March 20; 11.0, March 22; 12.0, March 25; 13.0, March 29; 14.0, April 6, and is now, April 13, of about the magnitude 14.3. After March 7 the cause of the outburst and fluctuations in light appeared to cease to act, and the star began to fade with such regularity that it promised to furnish a test of the correctness of Dulong and Petit's law of cooling. After three weeks, during which the light had diminished about six magnitudes, the change became less rapid and the light is now diminishing slowly. The remarkable increase of light of more than half a magnitude between February 16 and 17 was shown by various series of observations. The reality of several smaller changes can also be checked by the variety of methods employed.

The spectrum was last photographed on March 29, when the star had the magnitude 13, but the bright lines were not well shown after March 24, when the magnitude was 11.6. The prin-

* Communicated by the author.

cipal bright lines faded in the order K, H, α , F, h and G, the latter line becoming much the brightest when the star was faint.

A complete discussion of these measures will be published shortly. Observers are invited to send to the undersigned any comparisons they may have made of the light of the Nova with other stars. Observations are particularly desired on those nights on which it was cloudy at Cambridge.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.,

April 14, 1892.

STARS HAVING PECULIAR SPECTRA.*

M. FLEMING.

A recent examination of photographs of stellar spectra taken with the 8-inch Draper telescope, at Cambridge, and with the Bache telescope under the direction of Professor Wm. H. Pickering, at the station near Arequipa, Peru, adds to our list of objects of interest the stars given in the following table. The successive columns contain the designation of the star, the approximate right ascension and declination for 1900, the magnitude, and a brief description of its spectrum. The date and station at which the photograph was taken are given in the last two columns.

Design.	R. A.	Decl.	Mag	Description.	Date.	Station.
	1900 h m	1900 °				
DM. + 53° 379	1 38.7	+ 53 28	9.4	IV Type	Dec. 30, 1891	Cambridge.
DM. + 38° 2389	12 54.7	+ 38 20	8.6	IV Type	Mc. 28, 1892	Cambridge.
Z. C. XVh 4129	16 0.6	- 25 57	8½	V Type	Aug. 5, 1891	Arequipa.
A. G. C. 24550	17 57.7	- 24 22	6.1	F line bright	Aug. 2, 1891	Arequipa.
DM. - 11° 4593	18 13.5	- 11 40	8.7	V Type	July 14, 1891	Arequipa.
DM. - 61° 2233	21 57.6	+ 62 0	7.0	F line bright	Feb. 18, 1892	Cambridge.

The spectra of the third and fifth stars in the above list are of the same class as those given in the list published in the *Astronomische Nachrichten*, Bd. 127, p. 3, and they increase the number of these objects to 40. The galactic longitudes of these two stars are 290° 39' and 347° 36' respectively; their galactic latitudes are +17° 39' and +0° 35'. The spectrum of the fourth star shows other bright lines besides F.

An interesting change has taken place in the spectrum of 11 Monocerotis (H.P. 1220), magn. 4.2, whose approximate posi-

*Communicated by Edward C. Pickering, Director Harvard College Observatory.

tion for 1900 is in R. A. 6^h 24.0^m, decl. $-6^{\circ} 58'$. A bright line near F changes its position with regard to that line in a manner similar to the bright lines in β Lyræ. Photographs taken with the 11-inch Draper telescope on Dec. 14, 1888, Dec. 23, 1889, and Jan. 22, 1890, show this line as having a shorter wave-length than F, while those taken on Feb. 16, 1892, and Feb. 18, 1892, show it as having a greater wave-length. A detailed study of this object will be made.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., April 14, 1892.

THE TRUE FORM OF ALGOL'S LIGHT CURVE.*

J. PLASSMANN.

During the winter of 1890-91 I observed Algol not only at times of minima, but also, whenever this was possible, several times every clear evening. In all cases the star was compared with three comparison stars— α Persei, γ Andromedæ and ε Persei. On moonlight nights no observations were made. Ordinarily I did not know how far Algol was from a minimum. The observations† were carried on up to March, 1891, after which the constellation was too near the horizon.

The method of observation has the advantage that it is independent of the scale of the comparison stars. For if the three algebraic differences, $\beta - \alpha$, $\beta - \gamma'$, $\beta - \varepsilon$, have been determined by the observations, then:

$$\frac{1}{3}[(\beta - \alpha) + (\beta - \gamma') + (\beta - \varepsilon)] = \beta - \frac{1}{3}(\alpha + \gamma' + \varepsilon) = s.$$

The zero-point for s is thus the arithmetical mean of the brightness of the three comparison stars. I have used the same method advantageously for a number of variable stars with slight light-changes, e. g., α Cassiopeiae, γ Geminorum, λ Tauri, β Pegasi, δ Orionis, μ Cephei.

To my eye the differences Algol— ε Persei, and Algol— γ Andromedæ are generally positive; β Persei— α Persei is generally negative. The times of observation were then reduced to Paris time and to the Sun; several observations and times of observations were united into means after the times had been arranged according to the phase, i. e., the time elapsed since the last minimum. The values are given in the following table:

* Communicated by the author.

† See my paper, "Beobachtungen veränderlicher Sterne, III. Theil." Cologne, 1891.

Phase:	3 ^h 39 ^m	10 ^h 44 ^m	21 ^h 1 ^m	35 ^h 57 ^m	45 ^h 43 ^m	58 ^h 30 ^m	65 ^h 8 ^m	66 ^h 2 ^m
<i>s</i>	+ 0.58	+ 2.59	+ 2.30	+ 2.56	+ 2.47	+ 2.62	+ 1.30	- 2.76
<i>n</i>	10	41	37	35	31	52	11	6

Sum: 223 observations or 669 estimates.

Here *s* has the signification mentioned above; *n* is the number of observations, each of which consists of three estimates.

The figures appear at first glance to run very irregularly. Some weeks ago I first saw Herr Scheiner's pamphlet: "Untersuchungen ueber den Lichtwechsel Algols nach den Mannheimer Beobh. von Professor Schoenfeld in den Jahren 1869-1875." From this pamphlet, which was published at Bonn in 1882, it appears that Schoenfeld made 357 observations of Algol at times other than minima with a view of discovering a possible variability of Algol during the 60 hours in which it was formerly considered to be constant. Each observation consists of two estimates, so that 714 estimates are given in all, while my 223 observations represent 669 estimates. Consequently I venture to believe that my observations are somewhat more reliable than those of my late teacher, because Schoenfeld's notes are scattered over a longer time, and because my observations were only made when there was no disturbing influence of moonlight, while Schoenfeld evidently observed even in the moonlight. Forming means by the same method that I have myself employed more recently, (see page 13 of his pamphlet) Scheiner finds "that the full light of Algol can be regarded as entirely constant during the mean course of a period." Scheiner united his observations by tens (20 estimates) to form a single mean. A further contraction of these figures, however, gives the following table, in which *n* is as before, while *N* is the step according to Scheiner's scale:

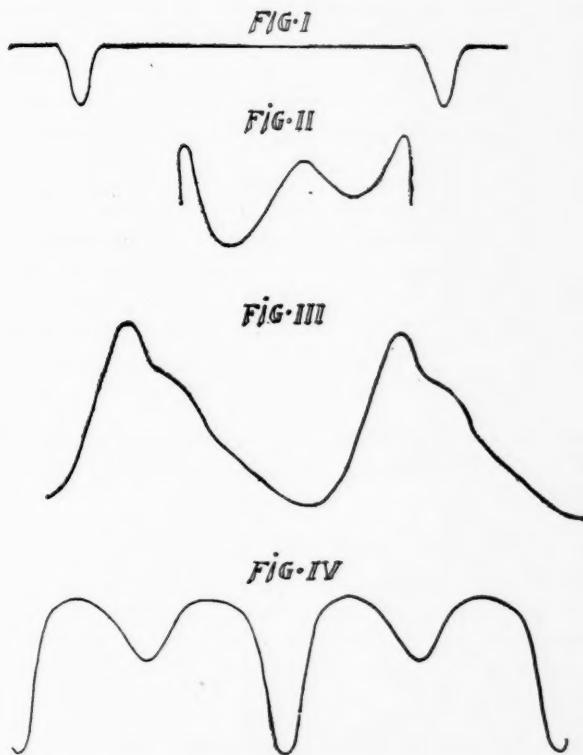
Phase:	10 ^h	20 ^h	30 ^h	40 ^h	50 ^h	59 ^h
<i>N</i> :	20.41	20.36	20.40	20.44	20.41	20.45
<i>n</i> :	60	60	60	60	60	57

Here a minimum at 20^h is at once evident. The question then arose whether my own observations might not be united with Schoenfeld's. After several trials I found the equation:

$$N = 19.497 + 0.37s.$$

Reducing my values of *s* to the scale of *N* by the aid of this equation, the following table results, in which Schoenfeld's times and mean values are somewhat more accurately given than in the one above.

Phase.	Brightness Schoenfeld.	Number of Observations.	Brightness Plassmann.	Number of Observations.
7 ^h 25 ^m	20.360	30		
10 44			20.455	41
12 20	.463	30		
19 52	.355	60		
21 1			.348	37
29 48	.403	60		
35 57			.444	35
39 50	.438	60		
45 43			.411	31
49 20	.412	60		
57 11	.490	30		
58 30			.466	52
61 45	.397	27		



It is at once evident that both sets of observations follow the same law. It may therefore be regarded as proved that Algol during the time of its full light undergoes certain variations, such as are shown in *Fig. 2*.

In this curve the light-changes are shown on a scale 250 times as great as that used in *Fig. 1*, which is the general curve of Algol according to Scheiner. The curve seems to have three maxima and three minima, as follows:

Minimum.	Maximum.
0 ^h 0 ^m	12 ^h 30 ^m
21 36	37 12
47 0	57 40

These points divide the curve into six nearly equal parts; exactly equal divisions would give:

0^h 0^m, 11^h 28^m, 22^h 56^m, 34^h 24^m, 45^h 52^m, 57^h 20^m, 68^h 48^m.

This result recalls the light-curve of β Lyrae, (*Fig. 4*, from Argelander's *Commentatio altera*) being divided by its maxima and minima into four nearly equal parts. But perhaps this agreement is only accidental. The slight undulations in Algol's brightness also recall the inflections in the descending branch of the curve of δ Cephei (*Fig. 3*, after Heis) and γ Aquilæ.

Earlier observations by Schoenfeld are given in his article "Der Lichtwechsel der Sterne Algol in Perseus." (36. Jahresbericht der Mannheimer Vereins für Naturkunde.) They were made between 1859 and 1870; the mean values are given in the following table:

Phase:	h	h	h	h	h	h	h
N'	7.57	20.17	28.19	39.31	47.89	54.63	60.59
N'	20.77	20.58	20.88	21.10	21.04	21.04	20.73
N obs.:	20.393	20.365	20.410	20.443	20.434	20.434	20.432
n :	5.	5.	5.	5.	5.	5.	5.
N comp.:	20.380	20.351	20.388	20.439	20.408	20.454	20.390
Comp.-obs.:	- 0.013	- 0.014	- 0.022	- 0.004	- 0.026	+ 0.020	- 0.042

Here N' is the brightness on Schoenfeld's earlier scale; its mean = 20.88, while Scheiner's mean = 20.41. The equation of reduction is

$$N = 20.41 + 0.15(N' - 20.88),$$

by means of which the third line (N , obs.) has been calculated. Every value is the result of 5 observations ($n = 5$); their accuracy cannot therefore be regarded as very great. The curve (*Fig. 2*) gives the values in the last line but one (N , comp.); the difference (comp.-obs.) is evidently not very marked; though N' is the result of only 5 observations. In Zoellner's "Grundzüge einer allgemeinen Photometrie der Himmels," 4 photometric observations of Algol are given, each the mean of 4 measures, and all made, curiously enough, during the time of full light. In the first two cases Algol was compared with ω Persei, in the third with χ Persei; this case could be reduced to the others by the equation

$$\log \frac{\beta}{\chi} + \log \frac{\chi}{\omega} = \log \frac{\beta}{\omega}.$$

But the fourth observation (1860, Sept. 27), in which Algol was compared with δ Persei, could not be used, on account of a lack of information in regard to the comparison star.

Time.	Phase.	$\log \frac{\beta}{\omega}$	N.	N. ''	N-N. ''
1859, Dec. 15,	6 ^h 7 ^m	39 ^h 16 ^m	0.97196	20.438	20.433
1860, Jan. 12,	9 15	26 15	0.91444	20.370	20.366
1860, Aug. 18,	12 1	54 59	1.00285	20.459	20.469
Mean:		0.96308	20.4223		

The above table gives Zoellner's times of observation reduced to Paris time and to the Sun, which, though possessing no great degree of accuracy, will suffice for our purpose. From them the phases were deduced, based on the minimum of 1856, Dec. 13, 7^h 59^m 31^s (Argelander B. B. VII, p. 38). The next column gives $\log \frac{\beta}{\omega}$ as deduced by Zoellner. For the third observation Zoellner took $\log \frac{\beta}{\omega} = 0.64954$; taking account of the weights I find from many other determinations by Zoellner that $\log \frac{\omega}{\beta} = 0.35331$, so that $\log \frac{\beta}{\omega} = 1.00285$. The fourth column gives N , taken from my curve. By the aid of the mean, as well as the three values of N , and also Zoellner's three logarithms, the equation of reduction is readily found to be

$$\frac{\log \frac{\beta}{\omega} - 0.96308}{10^{0.93120 - 10}} = N'' - 20.4223,$$

by means of which the logarithms may be reduced to the scale of N . The values of N'' thus found are given in the fifth column, and the small amount of the difference, $N - N''$, may be regarded as a photometric confirmation of the determinations obtained by an entirely different method. The probable errors of his logarithms, given by Zoellner, are much smaller than the amounts of the variations, and his attention ought to have been aroused by this fact. $\log \frac{\omega}{\beta}$ is indeed shown by the various determinations to vary considerably. But the probable errors are perhaps larger than this astronomer believed.

Besides my own observations during the winter of 1890-1891 Herr Pannekoek of Leyden, Holland, made some observations of Algol during its times of full brilliancy, but they are not yet num-

erous enough. It is very desirable that as many as possible accurate photometric observations be made.

To explain the changes in Algol's full light, atmospheric tides in the principal star may be suggested, and also a faint light proper to the satellite. A comparison of Zoellner's figures with my own and Schoenfeld's early and more recent ones shows that the amplitude of the variations is different in different years. But the reality of these differences may be doubted, as they may be caused by the methods of observation.

WARENDORF (Westfalen, Germany), 1891, Dec. 2.

ON THE DISTRIBUTION IN LATITUDE OF SOLAR PHENOMENA OBSERVED AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE, DURING THE SECOND HALF OF 1891.*

P. TACCHINI.

The following results were determined for each zone of 10° , in both hemispheres of the Sun:

PROMINENCES.		
1891.	Third Quarter.	Fourth Quarter.
$90^{\circ} + 80^{\circ}$	0.001	0.000
$80 + 70$	0.000	0.007
$70 + 60$	0.003	0.024
$60 + 50$	0.122	0.173
$50 + 40$	0.133	0.088
$40 + 30$	0.076	0.072
$30 + 20$	0.120	0.068
$20 + 10$	0.055	0.059
10 . 0	0.042	0.042
	0.552	0.533
$0 - 10$	0.020	0.018
$10 - 20$	0.038	0.066
$20 - 30$	0.077	0.085
$30 - 40$	0.111	0.083
$40 - 50$	0.112	0.101
$50 - 60$	0.085	0.096
$60 - 70$	0.004	0.018
$70 - 80$	0.001	0.000
$80 - 90$	0.000	0.000
	0.448	0.477
FACULÆ.		
1891.	Third Quarter.	Fourth Quarter.
$50^{\circ} + 40^{\circ}$	0.000	0.007
$40 + 30$	0.027	0.051
$30 + 20$	0.259	0.221
$20 + 10$	0.324	0.272
10 . 0	0.114	0.088
	0.724	0.639

* Communicated by the author.

1891.	Third Quarter.	Fourth Quarter.
0 — 10	0.016	0.015
10 — 20	0.108	0.118
20 — 30	0.108	0.206
30 — 40	0.038	0.022
40 — 50	0.006	0.000
	<hr/>	<hr/>
	0.276	0.361

1891.	SPOTS.	Third Quarter.	Fourth Quarter.
$40^{\circ} + 30^{\circ}$	0.000	0.000	
$30 + 20$	0.250	0.271	
$20 + 10$	0.472	0.390	
10 . 0	0.014	0.017	
	<hr/>	<hr/>	
	0.736	0.678	
0 — 10	0.000	0.017	
10 — 20	0.125	0.169	
20 — 30	0.111	0.136	
30 — 40	0.028	0.000	
	<hr/>	<hr/>	
	0.264	0.322	

1891.	ERUPTIONS.	Third Quarter.	Fourth Quarter.
$40^{\circ} + 30^{\circ}$	0.053	0.000	
$30 + 20$	0.368	0.000	
$20 + 10$	0.263	0.000	
10 . 0	0.105	0.000	
	<hr/>	<hr/>	
	0.789	0.000	
$0^{\circ} - 10^{\circ}$	0.000	0.000	
10 — 20	0.105	0.000	
20 — 30	0.053	0.000	
30 — 40	0.053	0.000	
	<hr/>	<hr/>	
	0.211	0.000	

The solar prominences were thus more frequent in the northern hemisphere, while in the preceding quarter, as in 1890 and 1889, a greater frequency was always found in the southern hemisphere of the Sun. The faculae were also more numerous north of the equator, and the maximum of frequency occurred in the zones ($\pm 10^{\circ} \pm 30^{\circ}$), that is to say, in lower latitudes as compared with the prominences than was the case in the preceding quarter. The spots followed the same rule as the faculae, being most abundant north of the equator, with the maximum of frequency in the zones ($\pm 10^{\circ} \pm 30^{\circ}$). All the phenomena, including the eruptions, were most frequent in the northern hemisphere, and very feeble in the neighborhood of the equator and near the poles.

ROME, Italy, March, 1892.

THE DISTRIBUTION OF THE SOLAR PROMINENCES OF 1891.*

J. EVERSHED, JR.

In working out the relative distribution in latitude of the prominences observed by me in 1890, it was found that there was a well marked maximum of activity between the parallels of 40 degrees and 50 degrees on both sides of the equator. Besides this, other secondary maxima and minima were indicated in lower latitudes, which gave a wavy contour to the curve representing graphically the relative activities at the different zones. These lesser irregularities in the curve were thought at the time to be simply the result of insufficient observation, and that if the Sun could have been observed every day, instead of an average of only once in four the decrease in activity from the maximum to the equatorial minimum would have appeared far more regular.

But as further observation has tended rather to intensify than smooth away these peculiarities, I have thought it might be of some interest to put on record the results so far obtained.

A much more extended series of observations has been obtained during 1891. Mr. E. E. Read, of Camden City, New Jersey, using a 5-inch refractor and grating spectroscope, has observed the prominences during four months of the year, and he has kindly sent me the results obtained, which I have included with my own observations.

At Kenley, using a 2½-inch equatorial, armed with a spectroscope of 6 prisms, and circular slit, I have observed the Sun completely, as regards the prominences, on 123 days, and imperfectly on 11.

From the positions obtained it is found that the main features of the curve of 1890 are still maintained. In both years there are shown two principal maxima in the northern hemisphere, separated by a very pronounced minimum, whilst south of the equator there are three points of maximum.

In order to bring out any slow changes which may be in progress in the latitudes of these zones of greater activity, I have worked out three separate curves each representing equal periods of six months, beginning in July 1890 and ending December, 1891.

In the diagrams, Figs. 1, 2 and 3, solar latitude is represented in a horizontal direction, the equator on the left hand and the poles on the right, the north hemisphere being above the

* In the Journal of the British Astronomical Association.

horizontal line and the south below it. The distance of any point on the curve from the horizontal line is measured by the total number of prominences observed between each five degrees of latitude, multiplied by their average estimated magnitude.

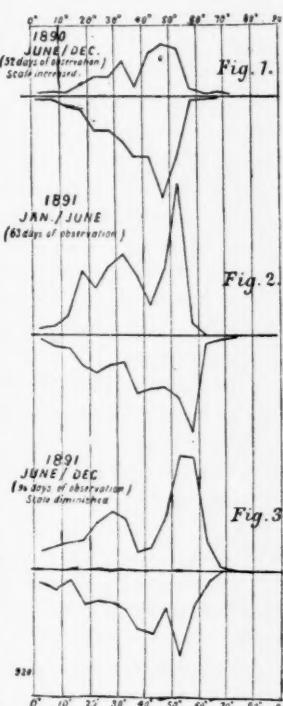
In order to make the three curves strictly comparable the vertical scale is made inversely proportional to the number of days of observation, so that the length of the ordinates also represents the average activity per diem of the various latitudes during the specified period.

From these diagrams it will be seen that the principal feature of the 1891 prominences is the great increase in the activity of the northern zones as compared with 1890. This increase is, in fact, so marked as to produce a considerable total balance in favor of the north hemisphere, whilst in 1890 the south took the lead. In this respect the prominences seem to have been influenced by the same cause that produced a change in the distribution of the spots from south to north, to which the Director of the Solar Section calls attention in her interesting summary of the solar phenomena of 1891.

The following table exhibits the relative activity of the two hemispheres, 100 representing the total activity:

Period.	Weighted.		Not Weighted.	
	North	South	North	South
1890, July-December	37	63	41	59
1891, January-June	55	45	53	47
1891, July-December	56	44	55	45

In the second column the prominences are "weighted" according to their estimated size, and in the third the relation is shown by taking the total numbers observed, without allowing for size. In the latter the difference between N. and S. is a little less in each case which shows that the prominences were, on the average, larger in the hemisphere where the greater number was seen. This is found to be an almost invariable rule, and the points at



maximum activity in the diagrams are therefore a little higher than they would have been had they simply represented the numbers observed unmodified by magnitude.

Another interesting feature shown is the advance towards the poles of the large high latitude prominences. In the northern hemisphere the principal maximum was between 40° and 45° during the first six months of 1890, and between 45° and 50° in the latter half of that year (see Fig. 1.). From January 1891 to June it advanced to between 50° and 55° (Fig. 2.), whilst in the last period (Fig. 3.) prominences were equally numerous and large between 50° and 60° . It is remarkable that the secondary north maximum between 30° and 35° has remained nearly stationary and has even receded a little towards the equator since June 1891, the result being a considerable widening of the intermediate minimum at about N. lat. 40° .

In the south the advance polewards has been less regular, starting in 1890 opposite the north maximum the most active zone advanced 10° in the second period (Fig. 2.), then receded 5° in the third whilst the two secondary zones in intermediate latitudes have remained nearly stationary.

In the equatorial regions prominences have been rare until the latter part of last year, when a considerable increase took place; but within 25° of the poles there has been a complete absence of them. Occasionally a little jet or cloud is seen, rising, perhaps, $20''$ above the chromosphere, and lasting a few minutes only; but these can hardly be called prominences; about a dozen in all have been seen during the year, none, however, within 6° of either pole.

No distinction has been made in the diagrams as to the various classes of prominences. Those of the metallic and eruptive kind have always occurred in the spot zones, but have only rarely been seen. On May 31 an exceedingly brilliant metallic prominence was on the W. limb, in N. lat. 19° , the form of which could be made out in the sodium and magnesium lines; also a line not previously seen, between B and C,* was strongly reversed. The hydrogen lines in this prominence showed bright extensions of equal length on each side, reaching in the case of D_3 half way towards D_2 . After an interval of 51 days (July 21) a very similar display was again seen on the W. limb, N. lat. 24; this was much better seen by Mr. Read, at Camden, N. J., who writes me that it was the brightest he had ever observed. It is rather

* The position of this line was not accurately ascertained, but it was probably the line at 6677 of Ångström's scale.

curious that another 51 days brings another bright metallic prominence on the N.W. limb, viz., that seen at Stonyhurst on September 10 (N. lat. 21°) accompanying the great spot group then on the limb.

Finally, on September 24, when the same spot region was on the E. limb, a bright dense prominence was seen there (in N. lat. 17°) which reversed Na and Mg very distinctly.

Large prominences of the eruptive order were observed on the following dates, all north of the equator, June 19 (described in Vol. I No. 9 of this Journal), July 9, N. lat. 28° E. limb, and October 13 near the equator on the W. limb. The latter may have originated in a higher latitude, it appeared like the flying *debris* of a great eruption, and showed a great velocity of approach in the highest filaments, C being displaced towards the blue by about 5 tenth-metres, which would correspond to 140 miles per second. In connection with the disturbance of June 17, described by M. Trouvelot, it may be interesting to state that the Sun was observed here on that date from 7 a. m. to 9. Nothing unusual was, however, seen on the disk (up to 8 a. m.), but a very brilliant and remarkable prominence was on the W. limb (P. A. 278° to 286° .) This had nearly died away at 8.55, when it was thought that the sun might safely be left to himself for the rest of the day, and observations were unfortunately discontinued.

With regard to the long duration of the disturbances which produce the quiet high latitude prominences, observations last year have confirmed those obtained previously. Some time during February a prominence was developed between 49° and 52° N. lat., and in a longitude that was on the E. limb on February 21, and this re-appeared with great punctuality every 14 days on alternate limbs. It was seen on March 5 and every subsequent semi-rotation till June 28. On April 18 it had apparently attained its greatest size and brightness, and occupied three or four days in passing the limb. It is, perhaps, worth remarking that between the limits of the northern maximum, namely 45° to 55° , the region of longitude 180° , from this prominence, was quite devoid of prominences throughout the period February—June, and for a distance of about 120° in longitude. Also in the same latitude south of the equator a well-marked minimum is shown on this side of the sun (corresponding roughly to heliocentric longitude 300° to 55° .) This minimum does not extend to the lower zones, however, and the north equatorial prominences up to lat. 45° seem to be much more

*Journal of the British Astronomical Association.

numerous between long. 180° to 360° during the first half of 1891, but, like the high latitude prominences, they become more equally distributed in longitude later in the year.

The results obtained during the past two years with regard to the distribution in latitude do not seem to be quite in accord with the law discovered by Prof. Ricco, according to which one would expect to find both in hemispheres a well-marked maximum of activity, corresponding to the new series of prominences, and approaching the equator, while the old series in high latitudes approached the poles. This is perhaps indicated in the two well-marked zones of the northern hemisphere which may represent the two series; but south of the equator this relation is less obvious.

Perhaps some future observations may bring it out more clearly.

Kenley, Surrey, England.

PHENOMENA OBSERVED ON THE GREAT SPOT-GROUP OF FEBRUARY. 1892.*

JULIUS PENYI.

The enormous spot-group, which entered on the eastern limb of the Sun's disc on Feb. 5, gave evidence of remarkable activity during its transit, not only by continual variation in form, but also by special phenomena.

On Feb. 7, at 10^h Kalocsa Mean Time, distinctly rose colored spots such as P. Secchi has described, were certainly seen over the two members of the group, by means of both the helioscope and the projection apparatus. At this time the C line was seen in the spectroscope to be reversed over both nuclei (and on Feb. 10 over three nuclei), and as bright as the background of the spectrum outside the spot; *i. e.*, as bright as the photosphere itself appears in this line. The F line was also seen bright, but much less distinctly, and only in the preceding spot, in which the C line was also more brilliant.

Other lines were not reversed, D₁, D₂ and b₁, b₂, b₃ being quite normal. Small distortions of the C line were noticed over other parts of the group.

Reversals in C were seen near the Sun's limb as early as Feb. 5, at $10^h 47^m$, but on the bright surface following the spot.

The time of passage of the center of the group over the west

*Communicated by the author.

limb of the Sun was determined by our calculations to be Feb. 19. The phenomena seen at this place with the spectroscope deserve particular mention. The base of a remarkably brilliant large prominence extended from position angle $219^{\circ} 20'$ to $216^{\circ} 26'$, and a few streamers rising from it met the limb again at $222^{\circ} 32'$.

The lower half of the prominence shone with an enormous brilliancy; the highest streamers were also so bright that the entire form could be seen with a widely opened slit, and its height was found by measurement to be $124''$. The lower and dazzlingly brilliant half was the seat of extraordinary phenomena. At the middle of the base a bright band crossed the entire field of view; *the prominence gave a continuous spectrum.*

The width of this band was not far from $1\frac{1}{2}^{\circ} - 2^{\circ}$; its edges were not sharp but diffuse. I estimated its brilliancy as about $1\frac{1}{2}$ times as great as that of the spectrum near the C line. The band was equally bright across the entire field of view, and ran through all the colors of the spectrum. The phenomenon was nevertheless not entirely new to me; on July 1, 1891, I saw for the first time a similar continuous spectrum in a prominence, but the appearance at that time showed itself only over a small breadth and height (C. R., CXIII, August 17). In the present case the band appeared over an extended region, and at a distinct elevation above the Sun's limb, where it offered a very striking appearance. As I was measuring the height of the prominence by means of transits across the slit, I noted at the same time at what height in the prominence,—*i. e.*, at what time—the band was first visible. I naturally obtained values differing considerably among themselves in the seven transits, because the region which produced the continuous spectrum was not sharply bounded at its upper surface, and therefore the band only gradually appeared and disappeared. From the seven transits I found $25''.5 \pm 3''.6$ as the height of that part of the prominence which radiated white light.

We are hence justified in drawing the very remarkable conclusion, that in the midst of this prominence there was a dust-like (staubartige) mass, composed of solid or liquid particles, with a breadth of between two and three thousand miles, and a height of 2,400 geographical miles, which gave this faint continuous spectrum.

It might also be assumed that the gases in the center were so condensed as to give a continuous spectrum. The C line was, in fact, remarkably widened, and had a dark line running through the center, *i. e.*, a reversal. This reversal was very distinctly seen in

the F line an hour later. It may be mentioned here that the continuous spectrum remained visible in all the colors throughout the entire time of observation, *i. e.*, until 11^h. The phenomenon recalls the prominences considered by M. Taechini to be dust-like, which up to the present time have only been observed at solar eclipses. (*Vide Memorie*, 1888, p. 41). It was not omitted to examine whether this form which appeared 1½ times as bright as the combined spectra of the atmosphere and corona, might not be seen on the Sun's limb without the aid of the spectrum. But as search made for this purpose by the assistant on the projected image of the Sun, and also with the helioscope, gave a negative result; no trace of a luminous form could be seen at the Sun's limb.

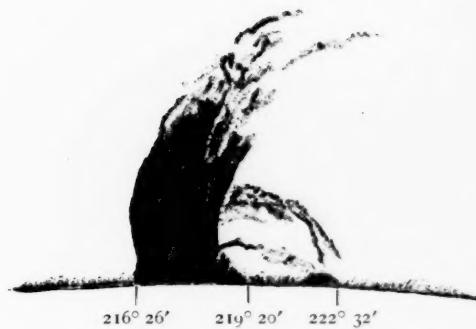
Another phenomenon, which, if not novel in character, was certainly so in brilliancy, was the appearance of large complete prominences in all of the metallic lines given in the following list, exactly in the position of the brilliant lower half of the prominence.

In most of these lines the prominence was so bright and sharp, that I could measure it through a widely opened slit with the filar micrometer. The form was the same in all the lines, and the details and structure were shown in the brighter ones. The height was also the same in all these metallic lines, which was easily determined by allowing the image of the prominence to move across the slit, and observing the simultaneous disappearance of the top of the prominence in all the lines in the same field of view.

The prominence soon commenced to break up. When I completed the transits at 9^h 39^m the height in the C line had decreased to 95", while the first transit, about 2^m before, gave 106". The same thing was true of the prominence in the line 6677; the first transit gave 62" for the height, the last only 44". The height of the region just described as giving the continuous spectrum, was, however, apparently increasing during the transits; but, on account of the ill-defined outlines of this object, this measure is too uncertain to be relied on. At 9^h 44^m I measured the height of the prominence in the red line 7055 with the micrometer, through a widely opened slit. The form and structure were particularly well seen in this line, even better than in 6677, and I found the height to be 39", exactly the same in both lines. Immediately afterward I found in the sodium line D₂ that $h = 34''.5$; the prominence was very brilliant in this line, and somewhat lower than in D₁. It should be noted that the prominence was at no time visible in the barium line 6140.5. This line was not even reversed at its base; there seemed to be only a break in the dark line.

About 9½^h the height in the corona line was found with the

PLATE XVIII.



In C line. Feb. 17, 9^h 20^m. h = 124".

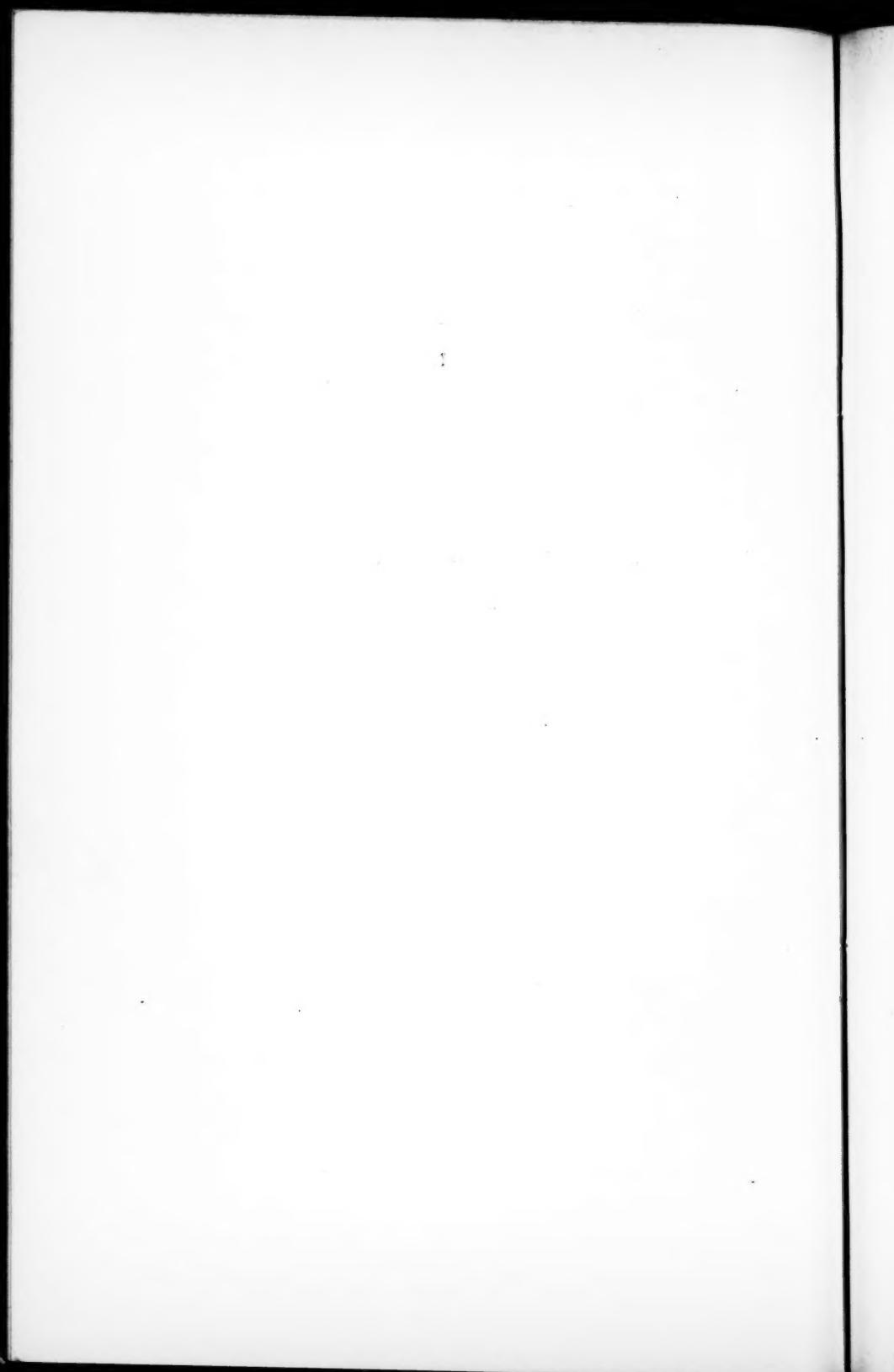


In λ 6677. 9^h 44^m. h = 39".4.



In Corona line (1474). 10^h 25^m. h = 33."3

Plate accompanying Herr Fenyi's Paper on the Great Spot-Group
of February, 1892.



iliar micrometer to be 33"; the very bright form showed two intense contiguous branches, inclined a little toward the pole, which corresponded exactly with two bright bands of the continuous spectrum running through them. This was also the case in all of the following lines.

At 10^h 38^m, the height of the prominence was once more measured in the 4923.1 line; I obtained 39".7 as the result of three closely agreeing transits.

The following table gives the times in Kalocsa Mean Time. The wave-lengths will merely serve for identification in Angström's map, from which they, as well as the corresponding metals, have been taken. Under the remarks, the measured heights of the prominence are given in seconds; "M" signifies a micrometer measure, and "D" a measure by means of transits across the slit.

Time.	Line.	Remarks.
9 ^h 30 ^m	C	124"; M.
9 ^h 37-39 ^m	C	106"—95"; D.
9 ^h 37-39 ^m	6677	62"—44"; D.
9 ^h 45 ^m	70 ..	39"; M; very distinct.
	D ₁ D ₂	35"; very distinct.
10 ^h 22 ^m	D ₃	46"; M.
	Corona	33"; M.
	5327 Fe	Line not seen with narrow slit. Prominence faintly visible with open slit.
	5323.4 Fe	
	5275	
	5269.5	Ca.
	5234.5	Co.
	5226.0	Fe.
	5207.7	
	5205.2	Cr; all 3 very bright; 5201.8 not reversed.
	5203.6	
	5197	Line itself not seen. Prominence only; exceedingly bright.
	5188.2	
	b ₁ , b ₂ , b ₃ , b ₄	Ti; in this line the prominence is about 3 times as bright as in the next.
	5019.3	Ni.
	5016.6	Fe?
	4945.5	Fe?
10 ^h 38 ^m	4923.1	Te; 40": D; about 3 times as bright in this line as in the next.
	4921	

No additional lines were seen in the region between 7055 and F.

In regard to the relation between this eruption and the great spot-group, the determinations of position show that, if we leave out of account the difference in longitude, the eruption took place at the edge of the southern spot nucleus, but entirely outside of it. Measures of the heliographic latitude showed the eruption to be between $-31^{\circ} 44'$ and $-34^{\circ} 38'$, while the heliographic latitude of the southern nucleus was calculated to be $-29^{\circ} 5$ on Feb. 15.

According to the observations the center of the eruption seems to have been somewhat beyond the Sun's limb, that is, somewhat nearer to the preceding spot, the heliographic latitude of which was found to be $-28^{\circ} 4$.

KALOCSA, Hungary, March 29, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in *Astro-Physics*, should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 448 for information in regard to illustrations, reprint copies, etc.

The New Star in Auriga.—As will be seen from Professor Pickering's article on another page, the Nova has decreased so greatly in brilliancy as to place it beyond the range of spectroscopic observation. But the discovery of the new star was sufficiently early to allow a large number of photographs to be secured, and these are now in process of reduction. Of the interesting and important changes in the spectrum which we noted in the April number, we have, as yet, learned nothing further.

In addition to the visual observations of the Nova's spectrum made at the Lick Observatory, Professor Campbell secured some photographs of the spectrum with the 36-inch, and these will shortly be ready for publication. At Hévény, Hungary, Herr Eugen von Gothard obtained a photograph extending far into the ultra-violet, and containing "an astonishingly large number of bright and dark lines." Among these "all the hydrogen lines of the white stars in Vogel's type *Ia* are visible as bright lines." (A. N. 3078). An account of Professor Vogel's determination of the Nova's motion in the line of sight is given on another page.

In the *Monthly Notices* for March, Mr. Maundler has a Note on the spectrum of Nova Aurigæ, as it was shown in a photograph made at Greenwich. As the 12½-inch refractor had been dismounted to give place to the new 28-inch (not yet completed), it was found necessary to attach an object-glass prism to the 9-inch photographic telescope. This instrument is carried by the heavy Lassell telescope, which shows considerable flexure when off the meridian, causing a drift in declination. In spite of his many difficulties, Mr. Maundler succeeded in obtaining a negative with an exposure of 70 minutes, on which were the following lines: bright lines—4919, 4860 (F), 4629, 4580, 4547, 4510, 4472, 4340 (G), 4229, 4174, 4101 (h), 3968 (H), 3933 (K), 3887.5 (α), 3834 (β); dark lines—4316, 4212, 4155, 4085, 3953, 3913.

Mr. Christie gives in the same number of the *Monthly Notices* a list of photographic determinations of the Nova's magnitude made at Greenwich, and notes a maximum on Feb. 3, and a secondary maximum about Feb. 18. Professor Pritchard communicates observations made photographically and also with the wedge photometer at the Oxford University Observatory, which indicate a slight secondary maximum on Feb. 22. Professor Pritchard's absolute values differ very widely from those of the Astronomer Royal.

Mr. Isaac Roberts obtained a number of photographs of the region about the Nova, and presents in the *Monthly Notices* measures of the diameters of the images compared with similar measures of 26 Aurigæ and DM, No. 899. "It will be observed, on examination of the table of the measured diameters of the Nova and the comparison stars, that no decided change in the brightness of the Nova has taken place during the interval between February 5 and 25, if we adopt the photo-images with 20 minutes exposure on the 25th as the standard; but if we adopt the image formed with 5 minutes exposure, there would be shown a fading of the light of the Nova between February 18 and 25."

The Relation between Sun-Spots and Auroras.—In the accompanying table the numbers of stations reporting auroras each day in the *Monthly Weather Review* are first arranged in periods of twenty-seven days six hours and forty minutes, the six hours or one quarter day being provided for by adding a day to each fourth period, and the forty minutes or one thirty-sixth day by adding a day to each thirty-sixth period, and then there is placed beneath the table thus constructed a section showing the attendant solar conditions as follows: The surface of the sun is considered to have been divided meridionally into as many lunes or sectors as there are days in each of the above periods. The amount of disturbance upon each of these sectors is obtained by entering in separate columns the sizes of all sunspots at all observations throughout the year as given

Table with Mr. Veeder's Article on Sun-Spots and Auroras. 435

in the Greenwich records. From these records also is obtained the location of each sector of the sun upon corresponding days of successive periods, thus determining where the columns indicating the amount of disturbance are to be placed. Thus upon the first day of each of these periods the same sector of the sun reached a certain location upon the visible surface, which location was in turn occupied upon the next day by the sector following and so on. The columns showing the amount of disturbance being entered accordingly it becomes apparent at a glance that the areas most persistently and actively disturbed were at the eastern limb appearing by rotation upon the series of dates characterized by recurrences of the aurora.

M. A. VEEDER.

The Relation between Sun-Spots and Auroras.—The following letter was received from Dr. M. A. Veeder in reference to his preceding note:

Dear Sir:—As bearing upon the question as to the location of the disturbed portions of the sun concerned in the production of the aurora I enclose a specimen extract from one of the tables I have constructed. The year 1879 being at a time of minimum sun-spots and auroras does not bring the relation out so strongly as appears in some other years. I have selected it simply for convenience because the table is short on account of the paucity of disturbance. The year following (1880) gives a similar table several feet in length and is consequently somewhat cumbersome. The year 1879 answers very well however as a specimen of the method when the conditions were not very strongly defined perhaps but were nevertheless distinct. Yours truly, M. A. VEEDER.

April 8, 1892.

Magnetic Disturbances and the Great Sun-Spot.—We are indebted to the Rev. Walter Sidgreaves for enlarged copies of the Stonyhurst horizontal force records secured on Feb. 11-16 and March 11-14, 1892. The curves are most interesting, and we only regret that they cannot be reproduced in these pages. So great was the deflection in several cases, that the spot of light left the field, and the extreme maxima are thus unrecorded. Accompanying the curves was the following letter:

STONYHURST OBSERVATORY, Lancashire, 21 March 1892.

Dear Mr. Hale:—I am sending by same mail prints of the magnetic storms accompanying the central passages of the great spot of February. Both storms are found on the second day after the passages of the C. G. of the group. We have a similar record for the two great spots of April, 1882, when the magnetic disturbances occurred with the first, one day after, and with the second, two days after the meridional passage; but there was no repetition of magnetic disturbance at the returns of these spots.

They are to some extent confirmations of André's law from the observations at Lyons, for the forces of activity may not correspond with the C. G. of the group.

I think you have the best means of determining the centre of greatest activity in a group of spots, and my present remarks are mainly intended to suggest a line of operations for you.

We have a good record of spots and magnetic curves; and I hope to find the time to test André's law by our comparisons. If I find the time you shall have the results.

Yours very truly,

WALTER SIDGREAVES.

A study of the Kenwood Observatory photographs of faculae will shortly be made as Father Sidgreaves suggests.

At present we can only state that the area of the faculose region about the spot-group was greater at the March central passage than at the February central passage, although the most marked magnetic disturbances were those of February. In March, however, there was less condensation of faculae in the near vicinity of the spots.

On account of its interest in this connection, we may be permitted to add a portion of a recent letter from M. Tacchini:

Collegio Romano, Roma, 17 Mars, 1892.

Mon cher et Honoré Colléague: J'ai appris avec le plus vif intérêt que vous avez réussi à bien photographier le bord solaire d'un seul coup. J'ai reçu aussi les deux belles photographies de l'appareil, qui vous sert pour les études photographiques sur le disque solaire. Vos observations seront très-importantes

surtout lorsqu'il s'agit des grandes taches ou des groupes des facules, qui, à la manière ordinaire, nous voyons seulement près du bord du Soleil. Comme j'ai noté dans le dernier numéro des *Memorie*, j'ai montré autrefois, qu'avec plus de probabilité, ce sont les phénomènes chromosphériques et ceux qui se produisent dans l'atmosphère du Soleil, qui correspondent aux phénomènes magnétiques terrestres; de manière que, si une tache passe sur le disque dans un état de calme, nous n'aurons pas des aurores ni des perturbations magnétiques correspondantes; au contraire, si un jour sur la tache ou sur les facules auront lieu des phénomènes extraordinaires, que nous ne pouvons pas constater avec les mouvements employés jusqu'à présent, on aura encore sur la terre et sur les autres planètes des perturbations. Or c'est avec vos observations qu'on pourra vérifier si un groupe de taches ou de facules en traversant le disque, se maintient calme toujours, ou si dans un temps donné se sont manifestés des phénomènes extraordinaires.

Votre dévoué, P. TACCHINI.

Stars of the First and Second Types of Spectrum.

To the Editor of *Astronomy and Astro-Physics*:

In your number for February Mr. Maunder discusses the binary stars with the first and second types of spectra. I believe Professor Pickering gives a somewhat wider extension to the second type than most spectroscopists, but I find on comparing Mr. Maunder's list with the *Draper Catalogue* that seven of the twenty-one binary stars which he treats as Sirian are referred to the second (or solar) type in that catalogue. These are ζ Cancri (spectrum F), ω Leonis (spectrum E), γ Virginis (spectrum F), η Corona Borealis (spectrum F), ξ Scorpis (spectrum F), μ Draconis (spectrum F) and β Delphini (spectrum F). This would leave only 14 Sirian binaries against 37 solars, or rather 36, for according to the *Draper Catalogue* the spectrum of 36 Andromedae is of the third type. Some of those classed by Mr. Maunder as Sirian are not in the *Draper Catalogue*, and possibly with further examination would give the predominating spectrum F. The spectrum assigned to μ^2 Bootis is probably that of the brighter star μ . About one-half the binaries which are found in the *Draper Catalogue* give the spectrum F.

This correction would reduce the density of the Sirian binaries from 0.0211 to 0.0153 or, if we omit the two doubtful stars O.2 4 and μ^2 Bootis, to 0.0066; a figure which contrasts strongly with that of the solar stars whose density would be but slightly reduced by the transfer. The high proportion of 36 to 14 however, seems to indicate that the solar stars are really more numerous than the Sirian, and that it is owing to the greater brilliancy of the latter (which renders them visible at greater distances) that the proportion appears to be about equal to the ordinary observer. The entire subject is well worthy of further investigation.

Dublin, Feb. 22. Truly yours, W. H. S. MONCK.

Photographic and Photometric Stellar Magnitudes.—In his article in the *Monthly Notices*, to which we have referred in a previous note, Mr. Christie remarks that "the Nova appears to be much brighter photographically than it is to the eye, judging from the visual estimations of magnitude which have been published." This is true when the Greenwich photographic values are compared with various visual determinations, but the Greenwich results are markedly different from any others we have seen. For instance, the magnitude on Feb. 13 is given by the Astronomer Royal as 4.50. Professor Pritchard's value for the same date, also determined photographically, is 5.35, while his measure with the wedge photometer is 5.28—in very good agreement with his photographic value. Mr. George Knott's visual estimation on Feb. 13 gave 5.3. In general, Professor Pritchard found the star to be slightly *fainter* photographically than visually, but in two or three cases this order was reversed, and in no instance were widely different values obtained by this observer. In a recent letter Mr. W. H. S. Monck calls attention to the same subject. He remarks that the photographic magnitudes in the *Draper Catalogue* do not at all correspond with the photometric. For stars brighter than 3 4 the photographic magnitude is less than the photometric; indeed the difference is so marked that Mr. Monck doubts if one photographic magnitude is as much as 0.75 photometric magnitudes. With faint stars this is reversed.

The Grating in Stellar Spectrum Photography—We learn from Professor Campbell that he has succeeded in obtaining good photographs of stellar spectra

with a grating. The spectroscope, which has already been described in *ASTRONOMY AND ASTRO-PHYSICS*, was attached to the 36-inch refractor of the Lick Observatory, and several negatives were secured of first and second magnitude stars, with iron comparisons, in the second order, exposures 20 and 30 minutes. With a larger grating the fourth order spectrum of Sirius was over-exposed in 30 minutes.

From these successful experiments it is evident that the great aperture of the 36-inch will allow the determination of the motion in the line of sight of stars too faint to be investigated elsewhere. Professor Vogel tried a grating in his earlier work, but the small aperture of his telescope caused him to reject it for prisms. Professor Young secured a photograph of the spectrum of Vega with a grating attached to the 23-inch Princeton refractor, but it was too faint for measurement. We therefore believe that Professor Campbell's photographs of stellar spectra are the first really successful ones obtained with a grating.

Prominence Observations with Small Telescopes.—We print on another page a paper by Mr. J. Evershed, Jr., which sufficiently demonstrates that success in solar spectroscopy is by no means wholly dependent on aperture. Mr. Evershed's outfit consists of a $2\frac{1}{2}$ inch equatorial, and a home-made spectroscope of 6 prisms. As we have before had occasion to note, Mr. Evershed has been making some experiments in solar prominence photography, and he has recently obtained a photograph of reversals in the C line with an exposure of 20 seconds on an isochromatic plate.

Comparative Photographic Spectra of the High Sun and the Low Sun, by Mr. F. McClean.—In addition to the series of photographs of solar and metallic spectra mentioned in our last number, Mr. McClean has now sent us a second beautiful set of five plates, in which the effect of atmospheric absorption on sunlight is brought out in the most striking manner. The region included is from H to A, and the map of terrestrial lines is thus most complete. For a short description of the apparatus used by Mr. McClean in his investigations, we may refer to a note in the last number of *ASTRONOMY AND ASTRO-PHYSICS*.

CURRENT CELESTIAL PHENOMENA.

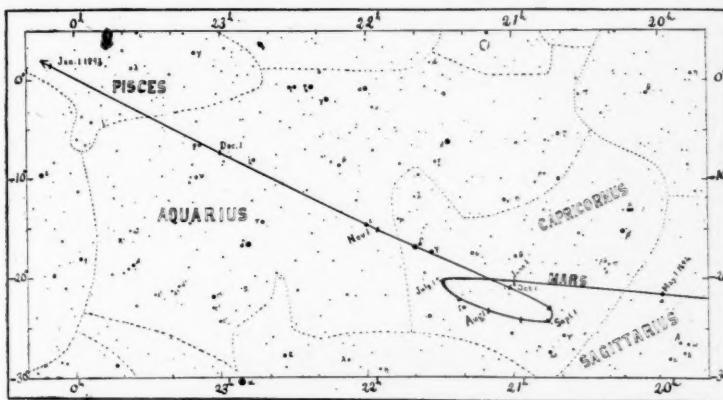
PLANET NOTES FOR JUNE.

Mercury will be at superior conjunction with the Sun June 20, so that during this month he will be observable only during the day in full Sunlight. Mercury and Neptune will be in conjunction June 10 at 11 P. M. central time, and Mercury and Venus July 1 at 2 A. M.

Venus, the very bright planet which we see toward the west every evening, will be at her greatest brilliancy June 2, and will after that time decrease rapidly. The illuminated portion of her disk decreases from 0.255 June 4 to 0.030 June 30, the apparent diameter increasing in the same time from 39" to 57". Venus will be in conjunction with the Moon June 25 at 7^h 05^m Central time.

Mr. Roger Sprague, of Berkeley, Cal., sends a sketch of Venus as seen through his 2-inch "spy-glass" (power 64) on the night of April 15, 1892. It shows a semi-circular dark shading enclosing the white center of the planet and looks suspiciously like an interference effect. Mr. Sprague also states that he saw Venus, when on the meridian, with the naked eye several times during the latter half of March. The planet is easily seen at any time during the afternoon if one knows just where to look.

Mars during June will be in the constellation Capricorn, being the most brilliant object in that part of the heavens. He is approaching the earth so that his apparent diameter will increase from 16" June 1 to 22" July 1. The summer months of this year will be very favorable for the study of Mars' surface markings, especially for observers in the southern hemisphere of the earth. We present this month a chart of Mars' path among the stars during the remainder of this year. From June to October he will describe an apparent loop in Capricornus, and after that will advance toward the northeast through Aquarius and Pisces.



Path of Mars in the Sky during 1892.

Jupiter is coming out of the morning twilight so that he may be seen fairly well for a couple of hours in the early morning. His declination is increasing so that in the coming months he may be observed under much more favorable conditions than during last year. He is to be found in the constellation Pisces, which, in June at 3^h A. M., is a little south of east and about one third of the way from horizon to zenith. Jupiter will be in conjunction with the Moon, 1° 09' north, June 19 at 5^h 40^m A. M., Central time.

Saturn will be at quadrature, 90° east from the Sun, June 13, crossing the meridian then about six o'clock P. M. He will be in conjunction with the Moon, 2° 05' south, June 2 a few minutes after midnight, and again on June 30 at 10^h 19^m A. M. During June Saturn may be well observed from 8^h to 10^h P. M., being then toward the southwest, about one-third of the way from horizon to zenith.

The rings now appear exceedingly narrow but will begin to open up somewhat after June. The belts on the disk of the planet are seen now at their best. With the 16-inch telescope we usually see four dark belts besides the black shadow of the rings which falls just a little to the south of where the ring crosses the planet's disk. The two belts in the southern hemisphere are much more distinct than those in the northern hemisphere. As they are seen projected upon the plane through the planet's center and perpendicular to the line of sight their distances from the equator are one-third and two-thirds of the planet's radius respectively. On the two hemispheres the belts are symmetrically situated. We have not yet been able to see any markings which would enable us to determine the planet's rotation period.

Uranus will be in good position for observation during June, as he crosses the meridian about nine o'clock. He is moving slowly westward in Virgo between *Spica* and the fifth magnitude star λ (See chart, Jan. No. p. 81). *Uranus* will be in conjunction with the Moon, 53' south, June 6 at 4^h 22^m A. M.

Neptune is behind the Sun.

MERCURY.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
June 5.....	3 47.4	+ 18 26	3 26 A. M.	10 49.1 A. M.	6 09 P. M.
15.....	5 11.6	+ 23 19	3 50 "	11 33.8 "	7 18 "
25.....	6 47.2	+ 24 40	4 39 "	12 29.8 P. M.	8 21 "

VENUS.

June 5.....	7 42.7	+ 23 29	6 58 A. M.	2 43.5 P. M.	10 29 P. M.
15.....	7 52.6	+ 21 37	6 39 "	2 14.2 "	9 50 "
25.....	7 46.8	+ 19 48	6 03 "	1 29.2 "	8 56 "

Date. 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
MARS.					
June 5....21 03.6	-20 13	11 23 P. M.	4 02.4 A. M.	8 42 P. M.	
15....21 15.2	-20 04	10 55 "	3 34.8 "	8 15 "	
25....21 22.8	-20 15	10 24 "	3 03.0 "	7 42 "	
JUPITER.					
June 5.....1 07.7	+ 5 55	1 44 A. M.	8 10.3 A. M.	2 37 P. M.	
15.....1 14.2	+ 6 32	1 08 "	7 37.4 "	2 07 "	
25.....1 20.0	+ 7 05	1 32 "	7 03.8 "	1 35 "	
SATURN.					
June 5.....11 39.6	+ 4 45	12 18 P. M.	6 40.0 P. M.	1 02 A. M.	
15.....11 40.6	+ 4 37	11 40 A. M.	6 01.6 "	12 23 "	
25.....11 42.1	+ 4 24	10 04 "	5 24.4 "	11 45 P. M.	
URANUS.					
June 5.....14 01.7	-11 51	3 39 P. M.	9 01.7 P. M.	2 25 A. M.	
15.....14 00.8	-11 47	2 59 "	8 21.5 "	1 44 "	
25.....14 00.2	-11 44	1 19 "	7 41.6 "	1 04 "	
NEPTUNE.					
June 5.....4 30.3	+ 20 19	3 59 A. M.	11 28.1 A. M.	6 57 P. M.	
15.....4 31.8	+ 20 22	3 21 "	10 50.3 "	6 20 "	
25.....4 33.3	+ 20 25	2 43 "	10 12.4 "	5 42 "	
THE SUN.					
June 5.....4 56.9	+ 22 40	4 16 A. M.	11 58.4 A. M.	7 40 P. M.	
15.....5 38.3	+ 23 22	4 15 "	12 00.4 P. M.	7 46 "	
25.....6 19.9	+ 23 23	4 17 "	12 0.25 "	7 48 "	

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magni- tude.	IMMERSION		EMERSION		Duration.
			Washing- ton M. T.	Angle f'm N pt.	Washing- ton M. T.	Angle f'm N pt.	
June 4	α Virginis.....	6	6 18	142	7 47	300	1 23
4	δ Virginis.....	5	14 20	126	15 16	282	0 56
5	π Virginis.....	6	5 10	92	6 13	344	1 03
5	B.A.C. 4591.....	6	10 18	56	11 11	12	0 53
12	ω Sagittarii.....	5	12 24	5	12 40	343	0 16
12	A Sagittarii.....	5	14 13	17	14 59	315	0 46

Minima of Variable Stars of the Algol Type.

U CEPHEI.

U CORONÆ.

U OPHIUCHI CONT.

R. A.....	0 ^h 52 ^m 32 ^s	R. A.....	15 ^h 13 ^m 43 ^s	16	10 P. M.
Decl.....	+ 81° 17'	Decl.....	+ 32° 03'	21	3 A. M.
Period.....	2d 11 ^h 50 ^m	Period.....	3d 10 ^h 51 ^m	21	11 P. M.
June 3	4 A. M.	June 6	9 P. M.	26	3 A. M.
8	3 "	13	6 "	26	11 P. M.
13	3 "	17	5 A. M.	27	8 "
18	3 "	24	3 "		
23	2 "	July 1	1 "		
28	2 "				
U OPHIUCHI					
δ LIBRAE.	R. A.....	17 ^h 10 ^m 56 ^s	Decl.....	20 ^h 47 ^m 40 ^s	
	Decl.....	+ 1° 20'	Period.....	+ 34° 15'	
R. A.....	14 ^h 55 ^m 06 ^s	Period.....	1d 11 ^h 56 ^m		
Decl.....	- 8° 05'	June 1	8 P. M.	5	4 "
Period.....	2d 07 ^h 51 ^m	5	4 A. M.	11	4 "
June 3	9 P. M.	5	midn.	14	3 "
10	8 "	6	8 P. M.	17	3 "
17	8 "	10	5 A. M.	20	3 "
24	7 "	11	1 "	23	3 "
		11	9 P. M.	26	3 "
		16	2 A. M.	29	3 "

Mr. Martha's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Mar. 1892.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

May, 1892.	May, 1892.	May, 1892.	May, 1892.
5 1.7 pm Di as	12 2.5 Mi as	17 2.5 Te en	8.7 Di es
2.0 Te as	5.0 Rh sh	En en	En en
3.1 Di es Rh en	5.3 En an	— 1.7	— 4.0
— 3.1" 5.7 Rh bs	3.6 Te bn	10.0 Di cs	Te en
3.2 Te es Rh en	6.6 En en Rh cs	3.8 Di bn	— 4.6
— 3.9 — 1.5	6.8 En as	9.2 Di en	Di an
4.7 Rh an	6.9 Mi en	25 5.7 En es	Rh en Te en
4.8 Di cs en ep	7.1 Te Ecl. R	6.9	+ 4.9
— 4.0 8.4 Te es	7.8 Di Ecl. R	7.2 Mi bs	
5.1 Te cs en en	10.4 Te ds	8.2 Di bn	
— 3.9 11.7 Eu en	18 2.3 Te ds	12.5 Rh es	
6.2 Mi es	13 12.3 am Te sh	4.2 Te sh	
7.2 Rh bn	3.6 pm Di sh	5.2 Te ba	
8.9 En an	4.1 En as	5.5 Mi en	12.9 Di Ecl. R
6 12.1 am Rh Ecl. R	4.5 Di bs	7.2 Te as	3.1 pm Rh cs Te es
12.1 Mi as	5.6 Te en En cs	9.3 En es	— 4.9
1.7 Rh en	— 3.1	10.4 Di es	En en
1.3 pm Titan bn	6.5 Mi an	10.9 Mi es	Mi as
1.3 En es	6.7 Di as	19 12.6 am Di as	Mi an
2.8 Di an	6.9 Te en Di cs	2.8 pm Rh en	11.2 Mi an
4.9 Mi es	— 2.4	4.1 Mi en	2.4 pm Di cs En en
5.0 Di bn	7.0 Te an	4.4 Te Ecl. R	— 4.0
7.2 Titan dn	9.0 Te bn	5.8 Te en	Mi as
7.7 Eu as	9.9 Di es En en	8.1 En en	En an
9.0 Di Ecl. R	— 4.0	9.5 Mi es	0.7 Rh en Di cs
9.7 Di en Titan	14 12.4 am Te Ecl. R	20 1.5 Te sh	— 6.3
— 6.0	12.4 Mi en	2.5 Te bs	Mi an
3.5 Mi es	4.6 Rh en Titan	5.2 Mi es	En as
9.4 Mi as	— 2.6	10.6 En an	Di Ecl. R
10.2 En es	5.1 Mi an	21 2.6 Rh ds	28 2.4 Rh Ecl. R
10.8 Rh es	5.4 Rh an	3.1 En es	2.5 Di bn
11.7 Di es	5.7 Te es	3.1 Te en	3.3
8 2.1 Mi es	5.7 Di es Titan	4.0 Di es	Di en
2.7 En an	6.1 Di es Titan	5.9 Rh sh	Mi an
3.8 Rh es Di es	6.7 En es	6.3 Di de	9.5 Te an
— 5.9	7.7 Te ds	6.5 Rh bs	11.5 Te bn
8.0 Mi as	7.9 Di an	6.8 Mi es	29 5.7 Te en En cs
9.0 En en	8.0 Rh bn	8.7 Di sh	+ 3.6
9 2.7 Di Ecl. R	9.6 Te sh	9.1 Rh as	Mi an
4.2 Di en	10.1 Di bn	9.4 Eu as	Te es
6.7 Mi as	10.6 Te bs	9.6 Di bs	8.1 En es
11.6 En an	11.1 Mi en	11.8 Di as	9.1 Di es
10 12.1 am Mi an	15 12.6 am Te as	22 5.4 Mi es	10.1 Te ds
12.4 Te -u	1.0 Rh Ecl. R	5.6 Titan dn	30 12.1 am Te sh
2.0 pm Di en	1.0 Eu en	7.8 Di en Te es	12.4 Titan es
3.1 En cs Rh en	3.8 pm Mi an	— 4.8	1.9 pm Titan as
— 2.8	4.3 Te an	9.5 Titan en	3.5 Rh ds
3.8 Di es Rh en	5.4 En en	11.1 En en Titan	5.0 Te en Titan
— 3.2	6.3 Te bn	— 2.8	— 3.3
4.0 En es	9.7 Mi en	11.3 Mi as	Mi an
5.3 Mi as	9.8 Te Ecl. R	23 12.0 am En es	Te an
5.3 Di es	11.2 Te en	12.9 Di an	6.8 Rh sh
6.5 Rh en Te es	16 3.0 Te es	4.0 pm Mi es	En en
— 4.5	3.6 Di es En en	4.4 En an	7.2 Rh bs
7.5 Di ds	— 4.0	6.3 Rh an	8.8 Te bn
10.0 Di sh	5.0 Te os	8.8 Rh bn	9.9 Rh as
10.3 En as	6.9 Te sh	9.9 Mi as	31 1.7 Di en
10.7 Mi an	7.9 Te bs	10.8 En en	3.6 Di en Te es
10.8 Di bs	8.0 En an	24 2.3 Di sh	+ 3.4
11.1 Te es	8.3 Mi en	2.6 Mi es	Mi an
11.2 En en	8.9 Te es en en	3.2 En es	Te es
3.9 Mi as	— 1.7	3.3 Di bs	Te ds
9.3 Mi an	9.9 Te as	5.5 Di as	9.4 Te sh
9.7 Te an	11.6 Rh es	8.8 Mi as	9.7 En an
10.7 Te bn			10.2 Mi en

May, 1892.	June, 1892.	June, 1892.	June, 1892.
10.4 Te bs	10.1 Mi es	7.5 En es	6.3 Di cs en cs
June 1892.	5 3.3 Mi en	7.9 Di es	— 4.0
1 2.2 En es	4.2 Te Ecl R	9.1 Mi as	6.9 Te cs Rh cn
2.8 Di es	4.9 En es	10.2 Di ds	+ 3.0
2.9 Mi an	5.2 Te en en es	10 3.5 Rh en Te es	7.0 Di cs Titan
4.1 Te an	+ 2.2	— 4.5	es — 4.3
5.1 Di ds	5.4 Di an	6.3 En en	8.0 Te es
6.1 Te bn	5.6 Te en	7.7 Mi as	10.0 Te ds
7.1 Rh an	7.6 Di bn	8.0 Rh an	17 2.8 Rh es
7.5 Di sh	8.7 Mi es	10.6 Rh bn	2.8 En en + 2.3
7.9 En es Rh en	11.2 En as	11 6.0 Di en Te es	3.5 Mi an
— 1.9	11.7 Di Ecl R	+ 50	4.1 Te es En en
8.3 Di bs	6 2.3 Te bs	6.3 Mi as	+ 3.0
8.5 En as	3.3 Rh Ecl. R	8.9 En an	5.3 Te es
8.8 Mi en	3.6 En en	12 3.3 Di ds	5.3 Rh ds
9.6 Te Ecl. R	4.3 Te as	5.0 Mi as	7.3 Te ds
9.7 Rh bn	4.6 Rh en	6.3 Di sh	8.7 Rh sh
10.5 Di as	7.3 Mi es	7.1 Di bs	9.2 Rh bs
11.0 Te en	8.1 Rh en En en	7.7 En as	9.3 Te sh
2 2.8 Te es	+ 4.0	9.3 Di as	9.4 Mi en
4.8 Te ds	9.6 Rh en Di cs	13 3.6 Mi as	10.2 Te bs
6.8 Te sh	+ 4.7	5.0 Rh cs Di en	14 4.0 Te an
7.4 Mi en	10.8 Titan en Te	+ 5.0	— 5.3 En an
7.7 Te bs	es — 4.9	9.0 Mi an	6.0 Te bu
9.7 Te an	7 3.0 Te en	10.2 En es	8.0 Mi en
11.1 En an	4.5 Titan dn	10.5 Di an	9.5 Te Ecl. R
11.7 Di an	5.9 Mi es	10.7 Te es	10.9 Te en
3 1.4 Te an	6.2 En an	14 1.5 Titan es Di	19 2.6 Te es
3.4 Te bn	8.4 Titan en	en + 5.6	4.1 En as
3.5 En an	8 1.3 Di bn	2.2 Mi as	4.2 Di Ecl. R
4.8 Rh cs Di en	1.6 Te as	2.7 En an	4.6 Te ds
— 6.1	1.8 Rh es	7.6 Mi an	5.6 Di en
6.1 Mi en	4.4 Rh ds	9.0 En en	6.5 En es Rh en
6.9 Te Ecl R	4.6 Mi es	9.3 Te an	— 3.5
8.3 Te en	5.0 En as	9.9 En en Titan	6.6 Te sh
9.9 En en	5.4 Di Ecl R	es + 2.8	7.5 Te bs
4 2.0 Di bs	6.8 Di en	11.3 Te bn	9.0 Rh an
2.1 Te ds	7.8 Rh sh	11.4 Titan es	9.5 Te as
2.3 En as	8.3 Rh bs	15 2.1 En es Titan	20 3.3 Te bu
4.1 Te sh	10.5 Mi as	es — 2.7	4.5 — 7 En closely
4.2 Di an	10.8 Rh as	3.1 Di as	followed
4.8 Mi en	9 3.2 Mi es	4.2 Rh Ecl. R	but not
5.0 Te bs	3.4 Te en en es	5.5 Rh en	overtaken
7.0 Te an	+ 4.0	6.1 Titan es En	by Di
7.0 Di cs En es	4.2 Di cs Te en	es — 4.0	5.3 Mi en
— 4.0	+ 4 3	6.2 Mi an	6.7 En es
			6.8 Di es

Occultations of Stars by the Planets.

[From *Astr. Nach.* No. 3073.]

STARS NEAR VENUS.

Date	Central Time of Conjunction.	Diff. of Decl.	Maximum Duration.	Magnitude of Star.
June 6	1 53 P. M.	— 20	40	9.0
	12 26 P. M.	— 50	70	6.0
	7 23 A. M.	— 3	47	9.2

STARS NEAR MARS.

June	8	5 07 P. M.	+ 29	21	9.5
	19	7 06 A. M.	— 30	36	8.5

STARS NEAR JUPITER.

June	9	8.1 A. M.	+ 56	1.5 ^h	8.8
	15	9.6 "	+ 120	1.6	8.8
	19	12.1 P. M.	— 59	1.6	7.7

Phases and Aspects of the Moon.

	Central Time.		
First Quarter.....		d	h m
Apogee.....	"	5	12 36 P. M.
Full Moon.....	"	10	7 32 A. M.
Last Quarter.....	"	17	3 01 P. M.
Perigee.....	"	21	8 18 A. M.
New Moon.....	"	24	8 07 "

Two New Asteroids.—These were discovered photographically by Wolf at Heidelberg, March 26 and 28. Their positions were as follows:

		R. A.	Decl.	R. A.	Decl.	Daily Motion.
No. 328	March 26.4111	12 ^h 13 ^m 59.1 ^s	+ 1°37'00"	- 48°	+ 14'	
No. 329	28.4460	11 22 44	+ 6 09	- 52	+ 1	

These will be numbered 328 and 329 if they receive subsequent observation so as to have their orbits determined. They were of the 12th and 13th magnitudes respectively.

COMET NOTES.

Designation of the Comets of this Year.—We were led into error last month, in designating the comets, by following the *Astronomical Journal*. A correction is made in the last number of the *Journal*. The first comet announced during the year was a re-observation of comet 1890 II (Brooks) which is not yet beyond the reach of the great telescopes. Swift's comet should be designated a 1892, Winnecke's periodic comet *b*, and Denning's new comet *c* 1892.

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 343.]

	Perihelion, March 31.			Perihelion, April 30.		
	R. A. h m	Decl. ° '	Light.	R.A. h m	Decl. ° '	Light.
June 9	21 32.1	- 35 59	0.47	17 39.7	- 44 00	1.77
19	21 37.5	- 38 12	0.42	17 40.8	- 46 52	1.38
29	21 35.8	- 40 11	0.37	17 42.2	- 48 28	1.01
	Perihelion, May 30.			Perihelion, June 29.		
June 9	12 53.4	- 8 40	1.20	11 18.6	+ 10 53	0.37
19	13 14.4	- 15 06	1.01	11 41.6	+ 5 41	0.36
29	13 38.6	- 20 48	0.82	12 06.4	+ 0 19	0.34
	Perihelion, July 29.					
June 9	10 24.6	+ 19 16	0.15			
19	10 47.6	+ 15 23	0.15			
29	11 11.8	+ 11 10	0.16			

Orbit of Comet a 1892 (Swift). From my own observations of March 9, 20 and 29, I have computed the following elements:

$$\begin{aligned}
 T &= 1892, \text{ April } 6, 80278 \text{ G. M. T.} \\
 \omega &= 24^\circ 41' 10'' \\
 \Omega &= 240^\circ 58' 8'' \\
 i &= 38^\circ 47' 25'' \\
 \log q &= 0.01158 \quad q = 1.0270
 \end{aligned}$$

O. C. WENDELL.

Harvard College Observatory, April 16, 1892.

Swift's Comet a 1892 is moving northeastward through the constellation of Pegasus. On May 10 it will be near star β , the upper star in the square of Pegasus, as one sees the constellation when looking toward the east. The best time to see the comet is between 3^h and 4^h A. M. During April the comet has been quite conspicuous, easily visible to the naked eye.

Mr. Barnard has sent us from Lick Observatory copies on glass of two remarkable photographs of the comet taken with a six-inch portrait lens, on the mornings of April 5 and 7 when the comet was near perihelion. These show the tail of the comet with surprising distinctness, and exhibit a wonderful amount of detail in its structure. The most striking features are the creases, knots and bends in the streams of luminous matter apparently flowing out from the head and forming the tail. Another curious feature shown is the darkening of the sky about the head of the comet and in some parts of the tail, which darkening cannot be merely the effect of contrast, as suggested by Mr. Barnard (see page 386), as the dark areas are not symmetrical with reference to the bright ones. The ap-

parent darkening of the sky about the head of the comet was noticed visually at Goodsell Observatory on the morning of April 23.

The ephemeris calculated by Mr. Sivaslian and Miss Harpham has represented the observations thus far so well that we continue it to the middle of June. The correction to the ephemeris on April 23 was -12° and $-12''$.

Ephemeris of Comet α 1892 (Swift).

[continued from p. 344.]

Gr. M. Noon.	App. R. A.	App. Decl.	$\log \Delta$	$\log r$	Br.
	h m s	° ' "			
1892 May 16	23 15 12.6	+ 30 02 53			
17	17 50.8	30 35 02			
18	20 27.4	31 06 32			
19	22 52.5	31 37 26	0.1456	0.0953	0.54
20	25 25.9	32 07 43			
21	27 57.8	32 37 42			
22	30 28.0	33 06 28			
23	32 56.6	33 34 59	0.1565	0.1082	0.49
24	35 23.5	34 02 55			
25	37 48.7	34 39 19			
26	40 12.2	34 57 11			
27	42 34.0	35 23 32	0.1668	0.1213	0.44
28	44 54.0	35 49 22			
29	47 12.4	36 14 42			
30	49 29.1	36 39 32			
31	51 44.1	37 03 55	0.1766	0.1345	0.39
June 1	53 57.2	37 27 50			
2	56 08.6	37 51 17			
3	23 58 18.3	38 14 17			
4	0 00 26.2	38 36 50	0.1857	0.1477	0.35
5	02 32.3	38 58 58			
6	04 36.6	38 20 41			
7	06 39.1	38 41 59			
8	08 39.8	40 02 54	0.1943	0.1608	0.32
9	10 38.7	40 23 26			
10	12 35.7	40 43 36			
11	14 30.9	41 03 24			
12	16 24.2	41 22 51	0.2021	0.1738	0.29
13	18 15.7	41 41 57			
14	20 05.2	42 00 43			
15	21 52.8	42 19 09			
16	0 23 38.6	42 37 15	0.2093	0.1867	0.26

Winnecke's Comet is moving southwest between the Great Bear and Leo Minor. It is growing rapidly brighter according to the following ephemeris by Dr. von Härndl, and is now visible in our five-inch telescope.

Ephemeris of Winnecke's Periodic Comet 1892.

[From *Astr. Nachr.* No. 3083.]

Berlin Midnight	App. R. A.	App. Decl.	$\log r$	$\log \Delta$	Br.
	h m s	° ' "			
1892 May 5	11 26 19.6	+ 44 25 43.4	0.0867	9.6970	2.71
6	24 48.7	28 42.1			
7	23 19.5	31 08.6			
8	21 52.3	33 03.6			
9	20 26.8	34 28.1			
10	19 03.2	35 23.3			
11	17 41.3	35 50.0			
12	16 21.2	35 49.6			
13	15 02.6	35 22.5	0.0596	9.6634	3.58
14	13 45.6	34 29.4			
15	12 30.0	33 11.2			
16	11 15.7	31 28.7			
17	11 10 02.6	+ 44 29 22.9	0.0460	9.6438	4.17

Berlin Midnight.			App. R. A.	App. Decl.	$\log \Delta$	$\log r$	Br.
	h	m	s	h	m		
May	18	11	8	50.5	+ 44	26	55.0
	19	7	39.3		24	05.2	
	20	6	28.9		20	53.7	
	21	5	19.1		17	21.4	0.0326
	22	4	09.5		13	29.0	
	23	3	00.0		9	17.4	
	24	1	50.5		4	47.8	
	25	11	00	40.6	44	0	00.3
	26	10	59	29.9	43	54	55.3
	27		58	18.2		49	33.4
	28		57	05.1		43	55.1
	29		55	50.1		38	00.7
	30		54	33.0		31	50.9
	31		53	13.2		25	25.2
June	1	51	50.2		18	43.7	
	2	50	23.4		11	46.0	9.9949
	3	48	52.4		43	4	31.4
	4	47	16.4		42	56	59.7
	5	45	34.6			49	10.6
	6	43	46.4			41	02.7
	7	10	41	50.7		32	34.0
	8	10	39	47.0		23	42.0
	9		37	34.4		14	23.5
	10		35	11.8		42	04
	11		32	38.0		41	54
	12		29	51.8		43	15.4
	13		26	52.0		31	32.2
	14		23	37.2		18	57.9
	15		20	06.0		41	05
	16		16	16.8		40	50
	17		12	08.0		40	34
	18		7	37.9		40	16
	19	10	02	44.6		39	57
	20	9	57	26.1		39	35
	21		51	40.2		39	11
	22		45	25.2		38	44
	23		38	38.9		38	13
	24		31	19.3		37	38
	25		23	24.7		36	58
	26		14	53.5		36	13
	27	9	5	44.8		35	22
	28	8	55	51.9		34	24
	29		45	32.6		33	17
	30	8	34	30.4	+ 32	02	12.7

Denning's Comet c 1892 is about five degrees north of α Persei and moving slowly southeast. It is extremely faint and will probably not be visible in very small telescopes. The following elements are by R. Schorr, of Berlin (*Astr. Nach.* No. 3082). The ephemeris has been extended from May 23 to June 15, by Miss Harpham. There seems to be a difference of about 18° and 10' between the two computers resulting probably from some error in the published elements:

$$\begin{aligned} T &= 1892, \text{May } 6.13922 \text{ Berlin M. T.} \\ \omega &= 126^\circ 39' 17.7'' \\ \Omega &= 252^\circ 55' 13.8' \\ i &= 89^\circ 49' 45.1' \\ \log q &= 0.298920 \quad q = 1.9903. \end{aligned}$$

Ephemeris of Comet c 1892 (Denning).

Berlin Midnight.	App. R. A.	App. Decl.	$\log r$	$\log \Delta$	Br.	
	h	m	s	h	m	
1892 May 5	3	0	37	+ 55	54.2	0.4258
6	4	24		55	40.0	0.2989
7	8	08		55	25.6	0.85
8	11	48		55	11.1	

Berlin Midnight.	App.	R. A.	App.	Decl.	log r	log d	Br.
	h	m	s				
May 9	3	15	23	+ 54	56.6	0.4311	0.2990
10	18	54		54	42.0		0.83
11	22	22		54	27.2		
12	25	46		54	12.3		
13	29	07		53	57.3	0.4362	0.2994
14	32	24		53	42.2		0.81
15	35	38		53	27.1		
16	38	48		53	11.9		
17	41	55		52	56.7	0.4411	0.3000
18	44	58		52	41.4		0.79
19	47	59		52	26.1		
20	50	57		52	10.8		
21	53	52		51	55.4	0.4458	0.3008
22	56	44		51	40.0		0.77
23	3	59	15	51	34.1	0.4476	0.3012
24	4	02	02	51	18.6		0.76
25		04	46	51	03.2		
26		07	28	50	47.8		
27		10	07	50	32.3	0.4519	0.3024
28		12	44	50	16.9		
29		15	18	50	01.4		
30		17	50	49	46.0		
31		20	19	49	30.6	0.4558	0.3039
June 1		22	46	49	15.2		0.73
2		25	11	48	59.7		
3		27	33	48	44.3		
4		29	53	48	28.9	0.4594	0.3056
5		32	11	48	13.6		0.71
6		34	27	47	58.2		
7		36	41	47	42.8		
8		38	53	47	27.5	0.4626	0.3075
9		41	03	47	12.2		0.69
10		43	11	46	56.9		
11		45	17	46	41.6		
12		47	22	46	26.4	0.5654	0.3097
13		49	25	46	11.2		
14		51	26	45	56.0		
15		53	25	45	40.8		
16	4	55	23	45	25.6	0.4679	0.3120
							0.66

NEWS AND NOTES.

It is expected that this journal will be mailed hereafter before the first day of each month of the year, except July and September, which are vacation months. Regular subscribers in America should receive their copies before the 5th and most of the foreign ones about the 12th of the month.

Portrait of Professor Adams which appeared in the April number of this journal was furnished with the compliments of the Astronomical Society of the Pacific. Credit for the same should have been so given previously.

Mr. T. J. J. See, author of the "History of the Color of Sirius," has been traveling recently in England. Writing from London, he gives an account of the views of prominent English astronomers, concerning the colors of the stars. He says: "It is chiefly the spectroscopists who consider the red stars the oldest, other astronomers regard them as equally likely to be younger than the blue ones and this is confirmed by colors of double stars."

Professor Pickering speaks of furnishing a number of articles for this publication during the present year containing results of important work well under way at the Arequipa station.

Report from Temple Observatory, Rugby, 1891. The Curator, Geo. M. Seabroke, reports for the year 1891, that Temple Observatory, at Rugby, has been open for instruction on 76 nights. As time has given opportunity, Mr. Highton has continued the measurements of the double stars, and Mr. Seabroke has given attention to the motion of stars in the line of sight. Instruction will also be given soon in photography as applied to Astronomy. For this purpose a 15-inch mirror, with focal length of 48 inches, has been mounted on the tube of the equatorial.

Harvard College Observatory, Arequipa, South America. Our frontispiece and articles in this issue by Professor W. H. Pickering concerning the Harvard College Observatory station at Arequipa, South America, make a theme of delightful interest. From a later private letter received during the last days of April, Professor Pickering says "I have recently received the February number of *ASTRONOMY AND ASTRO-PHYSICS* and find it very interesting reading. . . . In my last paper, page 12, line 5, (in this number page 361 line 40) 'Its spectrum it probably gaseous,' referring to 30 Doradus. This conclusion was arrived at from its shape and general appearance in the telescope. Since then I have been able to examine it through the prism, and find that its spectrum shows a strong green line. This would therefore seem to settle the matter and the word 'probably' in the above quotation should be left out.

Partial Eclipse of the Moon, May 11.—This will be almost a total eclipse, .953 of the Moon's diameter being immersed in the Earth's shadow. It will not be visible in the United States, except in the extreme eastern portion, where only the end of the eclipse will be seen. It will be visible generally in the western portions of Asia, in Europe, Africa, and the Atlantic Ocean.

The New Jena Glass. Professor Young in his article on the new spectroscope of Halsted Observatory makes a statement in regard to the Jena glass which is liable to misconstruction. He has reference, of course, to one kind of glass, a borate flint, and a potash crown. These two glasses in combination give, as Professor Young says, practically perfect color-correction, but must be protected in use to prevent tarnishing.

We have received three letters this week from parties interested in Jena glass, all fearful that Professor Young's remarks included Jena glass in general. In justice to Messrs. Schott and Gen., I should like to say that only a few of their glasses are perishable. Professor Young's objectives are of Jena glass but not the kind that rusts.

JNO. A. BRASHEAR.

Time of the Sun's Passing the Vernal Equinox.—A correspondent asks why the Sun passes the Vernal Equinox one day earlier this year than last. As the length of the solar year is approximately 365 $\frac{1}{4}$ days while the common year contains only 365 days, the Sun passes the Vernal equinox one quarter of a day later each year. But as we put into our year one extra day every fourth year, this throws back the spring equinox one day every fourth year, thus keeping it at nearly the same date for centuries. This year and next the passage of the vernal equinox will take place on March 19, astronomical time, or in the forenoon of March 20 civil time. The next year it will occur in the afternoon of March 20 civil time. In 1895 it will come on March 20 astronomical time, but on the morning of the 21st civil time. In 1896 another leap year will occur and the date will be set back one day.

Lick Observatory Lunar Photographs.—Referring to a note on the Lick Observatory negatives of the Moon in your April number, page 348, I wish to quote Professor Weinck's words in his letter to me dated April 9, 1891, as follows:

"Ich bemerke noch, dass Mädler und Neison den vom Krater A nordwestlich liegenden kleinen Krater unrichtig an den Aussenwall von *Thebit* verlegt haben. Es liegt gemäss der Photographic am Innenwalle, etc., etc."

This sentence was correctly translated and sent to the printer, who made the error of putting "N. W. on the crater *Thebit A*," instead of "N. W. of the crater *Thebit A*," in *Publ. A. S. P.* vol. III, page 253, line + 14.

This printer's mistake of a single letter was not discovered until I read the note in question. Whatever error there may be, it was not made by Professor Weinck, which is all that I am desirous of saying in this place. Be kind enough to print my letter in your journal and oblige,

Yours very sincerely,

Mount Hamilton, April 11, 1892.

EDWARD S. HOLDEN.

The Reduction of Rutherford Star-Plates. At the November meeting, 1891, of the National Academy of Sciences, held at New York City, Professor John K. Rees, read a paper entitled: Preliminary Notice of the Reduction of Rutherford Star-Plates, which was published in the last issue of *The School of Mines Quarterly*. From that paper we learn, that the best negatives by Mr. Rutherford previous to 1868 were taken by his 11½-inch photographic telescope. He made his own machine for measuring the star plates, which consisted in getting position-angle and distance of every star on the plate from a central star, the latter measure depending on a micrometer-screw. Plates containing the clusters of the Pleiades, Praesepe and others, were measured under the direction of Mr. Rutherford, and reduced by Dr. Gould, showing value, in the method for determining parallax and relative proper motion. Later, Mr. Rutherford made a telescope of 13-inches aperture which could be used for either visual or photographic work.

The measuring machine was also improved by which work was carried forward after 1872. In 1883 these instruments became the property of Columbia College, and in 1890 Mr. Rutherford gave all his best negatives to the same institution, a complete list of which has been prepared and published in the *Annals* of the New York Academy of Sciences, Vol. VI, June 1891. At the suggestion of Mr. Rees, the Pleiades-plates taken with the 13-inch telescope and measured by the improved machine, are in process of reduction by Mr. Harold Jacoby of the Observatory, and the work is well nigh completed, and it is said that the accuracy of it compares well with the best heliometer work. The results will soon be published in the *Annals*, and will fill about twenty folio volumes of two hundred pages each. This is only a part of the important labor undertaken with regard to the collections of the Rutherford star-plates.

Erratum.—In the last number of this publication, on page 348, in the note on Lick Observatory lunar photographs, the date Aug. 15, 1888, should read Aug. 16, 1888.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is \$4.00 per year, in advance. For foreign countries it is \$4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

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All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be smoothly and carefully made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. As a rule the publishers have had to re-draw the figures sent during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, twenty-five re-print copies, in covers, will be furnished free of charge. A greater number of re-prints of articles can be had if desired, at reasonable rates.

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